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ROCKET ASSISTED PROJECTILE (RAP) DEVELOPMENT PROGRAM

Part 4. 5"/38 SAFETY TEST PROGRAM

by

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ABSTRACT. The Safety Test Program for the 5-inch 38 caliber Rocket Assisted Projectile (5"/38 RAP) verified that RAP can be handled, stowed, and fired as safely as existing in-service projectiles loaded with Composition A-3 explosive. The presence of a solid-propellant rocket motor and percussion-actuated igniter did not present any unusual safety hazard. Sequential environmental, bullet impact, and slow and fast cookoff tests were conducted as required by WR-50 and MIL-R-23139. Optional and additional evaluations included rocket motor blast, adjacent detonation, propagation, ignition of unrestrained projectile, exposure to gun muzzle blast, gun-fired with clearing charge, and special igniter drop tests.

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FOREWORD

This report documents the 5-inch 38 caliber Rocket Assisted Projectile (RAP) Safety Test Program. Only those tests conducted by the Naval Weapons Center (NWC), China Lake, California, are reported herein in detail. However, tests conducted by the Naval Weapons Laboratory, Dahlgren, Virginia, are listed in the summary to present an overall view of the safety program.

The 5-inch RAP development program was accomplished under ORDTASK ORD-084-0241/200-1/W119-00-01 and is documented by a series of reports. Previous reports are:

NOTS TP 4018	Rocket Assisted Projectile Rotating Band Study
NOTS TP 4025	RAP Rocket Motor Summary Progress Report Fiscal Year 1965
NWC TP 4555	N-34 Propellant Characterization
NWC TP 4756, Part 1	Rocket Assisted Projectile (RAP) Development Program, 5"/38 and 5"/54 Sustainer Development
NWC TP 4756, Part 2	Rocket Assisted Projectile (RAP) Development Program, 5"/38 Booster Rocket Motor Development
NWC TP 4756, Part 3	Rocket Assisted Projectile (RAP) Development Program, 5"/38 Projectile Development

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CONTENTS

Introduction.. 1
Summary... 1
Hardware Description.. 5
  Warhead... 5
  Fuze.. 5
  Rocket Motor.. 5
Mandatory Tests... 9
  Environmental Sequence.. 9
  Fast Cookoff.. 13
  Slow Cookoff.. 16
  20 mm Bullet Impact... 18
Optional Tests.. 24
  Adjacent Detonation... 24
  Propagation... 24
  Rocket Motor Blast.. 27
Additional Tests.. 32
  Ignition of Unrestrained Projectile................................. 33
  Exposure to Gun Muzzle Blast.. 34
  Gun-Fired with Clearing Charge...................................... 34
  Igniter Drop.. 34
Conclusions... 36
Appendix - 5"/38 and 5"/54 In-Service Projectile
    Bullet Impact Test.. 38

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INTRODUCTION

The 5-inch 38 caliber Rocket Assisted Projectile (5"/38 RAP), Mk 57 Mod 0, was developed to increase the range of 5"/38 naval guns. Inactivation of battleships and reduction in the number of cruiser gun barrels have reduced the Navy's capability to deliver long- and medium-range gunfire support at a time when revised amphibious assault tactics require effective surface gunfire support at increased ranges. RAP helps to satisfy this requirement by increasing the 5"/38 projectile range and incorporating a more lethal antipersonnel warhead.

The safety requirements for RAP development were established by WR-50[1] for the warhead and MIL-R-23139B[2] for the rocket motor. Evaluation of RAP safety characteristics for conformance with these requirements was accomplished primarily by Development Test D-17 and Navy Technical Evaluation (NTE) Test T-5. Additional igniter drop tests were conducted throughout development and NTE for verification of igniter safety.

SUMMARY

An extensive series of environmental and safety tests was conducted during Fiscal Year 1968 to evaluate RAP safety characteristics and verify RAP conformance with the requirements set forth in WR-50 and MIL-R-23139. A summary of the test program is presented in Table 1. The test program established that RAP can be handled, stowed, and fired as safely as in-service 5-inch projectiles loaded with Composition A-3 explosive. The presence of a solid-propellant rocket motor and percussion-actuated igniter did not present any unusual safety hazard.

An environmental sequence consisting of temperature/humidity treatment, vibration, and 40-foot drop was conducted with nine all-up projectiles and three warheads. All were safe to handle for disposal.

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[1]Naval Weapons Requirements, WR-50, Warhead Safety Tests, Minimum for Air, Surface and Underwater Launched Weapons, dated 13 February 1964.

[2]Military Specification, MIL-R-23139B, Rocket Motors, Surface Launched Development and Qualification Requirements for, dated 18 August 1965.

TABLE 1. Summary of RAP Safety Test Program.

Test type	Test no.	Qty	Projectile Configuration[a]	Results
Sequential environmental (WR-50)	D-17	3	CVT fuzed	
Temperature/humidity	T-5	3	CVT fuzed	All safe to handle for disposal
Vibration	T-5	3	PD fuzed	
40-foot drop	WT-4A	3	W/H only	
Bullet impact (WR-50)	D-17	1	CVT fuzed	Into warhead - burned
	D-17	1	CVT fuzed	Into motor - burned
	T-5	1	CVT fuzed	Into warhead - pressure rupture
	T-5	1	PD fuzed	Into warhead - pressure rupture
	T-5	1	PD fuzed	Into warhead - low order detonation
	T-5	1	PD fuzed	Into motor - pressure rupture
	WT-4A	1	W/H only	Pressure rupture, burned
	WT-4A	1	W/H only	High-order detonation
Slow cookoff (WR-50)	D-17	1	CVT fuzed	High order, explosive 350°F, propellant 338°F
	T-5	1	CVT fuzed	High order, explosive temp unknown, propellant 348°F
	T-5	1	PD fuzed	High order, explosive temp unknown, propellant 347°F
	T-5	1	W/H only	High order, 353°F
	T-5	1	Mtr only	Burned, 463°F
	WT-4A	2	W/H only	High order, 350 and 367°F
Fast cookoff (WR-50)	D-17	1	CVT fuzed	Low order after 3 min 15 sec
	T-5	1	PD fuzed	High order after 3 min 55 sec
	T-5	1	CVT fuzed	High order after 2 min 40 sec
	T-5	1	W/H only	Low order after 5 min 45 sec
	T-5	1	Mtr only	Burned after 5 min 50 sec
	WT-4A	1	W/H only	High order after 2 min 20 sec
	WT-4A	1	W/H only	Low order after 5 min 10 sec

TABLE 1. (Cont'd).

Test type	Test no.	Qty	Projectile Configuration[a]	Results
Rocket motor blast (WR-50, optional)	T-5	3	CVT fuzed	Side-by-side - no effect
	T-5	2	CVT fuzed	Base-to-nose - melted cap and part of fuze
	T-5	2	CVT fuzed	Base-to-base - acceptor motor ignited
Adjacent detonation (WR-50, optional)	D-17	1	CVT fuzed	Hurled 147 feet, no detonation
Propagation (WR-50, optional)	T-5	6 5 1	PD fuzed CVT fuzed No fuze	9 high order, 3 low order
Ignition of unrestrained projectile	D-17	1	CVT fuzed[b]	Flew 2,620 ft, AD fuze safe
Exposure to gun muzzle blast	D-17	2	CVT fuzed[c]	No effect
Gun-fired with clearing charge	D-17	1	CVT fuzed	Ignited motor, normal flight
Igniter drop on 3/4-inch-diameter steel stud	—	65	Igniters installed in 60-lb fixture	Mod 0 actuated at drops of over 2 feet, no actuation of Mod 1 at 3 feet

[a]CVT fuzed: Projectiles configured with Mk 357 Mod 0 Fuze and Adapter Assembly (Adapted Army M514 fuze).

PD fuzed: Projectiles configured with Mk 29 Mod 3 point detonating fuze and Mk 52 or Mk 43 auxiliary detonating fuze plus supplementary Composition A-3 pellets.

[b]Inert warhead.

[c]Inert motor and warhead.

Six slow cookoff tests resulted in six high-order warhead detonations at temperatures between 350 and 367°F. A rocket motor subjected to slow cookoff ignited at 463°F. Fast cookoff tests of three all-up rounds and three warheads resulted in three high-order and three low-order detonations. The all-up rounds experienced two high-order and one low-order detonations, with the minimum time to reaction being 2 minutes 40 seconds for a high-order detonation. Minimum time to reaction for the three warheads (one high-order and two low-order detonations) was 2 minutes 20 seconds for the high-order detonation. A rocket motor subjected to a fast cookoff test ignited after 5 minutes 50 seconds.

Eight 20 mm bullet-impact tests were conducted during which six warheads and two motors were impacted by a 20 mm M95 armor-piercing (AP) nonincendiary projectile. A reaction occurred in all tests, ranging from pressure ruptures to a high-order warhead detonation. WR-50 requires that no violent reaction occur; however, tests conducted with standard in-service projectiles, which were developed before the existence of WR-50, also incurred a large number of violent reactions.

Several optional tests were conducted and acceptable results were obtained. Seven all-up rounds were subjected to rocket motor blast. The only reaction was a rocket motor ignition on a round placed base-to-base with the donor rocket motor. During the adjacent detonation test, an all-up round was hurled 147 feet without incurring a reaction. For the propagation test, 12 RAP were positioned in a simulated shipboard stowage bin and a RAP near the center was detonated. As expected, a number of detonations occurred simultaneously. It was estimated that the detonations included nine high order and three low order.

Additional tests were conducted to gather data in areas not covered by WR-50 or MIL-R-23139. An unrestrained RAP, which was purposely ignited, flew and bounced 2,620 feet across the test range without detonating or arming the fuze. Two RAP were exposed, one with the fuze up and one with the igniter up, 5 feet in front of and 5 feet below a 5"/38 gun muzzle and the gun was fired. No damage or reaction was sustained by the fuze or igniter. A round fired with a reduced clearing charge attained normal ignition and flight; however, the range was significantly reduced, as expected. Igniter drop tests were conducted throughout the development program. In these tests, igniters were attached to 60-pound weights and dropped onto 3/4-inch-diameter studs. With the original design (Mk 279 Mod 0) drops in excess of 2 feet resulted in igniter actuation. Structural improvement of the spring retainer eliminated this problem in the Mk 279 Mod 1 igniter even though a more sensitive primer was incorporated into the design. A series of six drops with the Mod 1 igniter, at 3 feet, resulted in six "no fires." The modified igniter was further evaluated with 40-foot drops onto steel plate and remained unactuated in all cases. As a final test, loaded igniters were subjected to 320°F for 4 hours without incurring autoignition.

HARDWARE DESCRIPTION

All test projectiles were basically the Mk 57 Mod 0 5"/38 RAP shown in Fig. 1. The following is a physical and functional description of the RAP test hardware.

The Mk 57 RAP consists of a solid-propellant rocket motor, an explosive-filled warhead, and a point detonating (PD) or controlled variable time (CVT) fuze. The 23-inch, 55-pound Mk 57 has the same shape as the standard Mk 49 projectile except the base has been boattailed and the length increased 2 1/8 inches. The warhead and motor case are assembled by means of a threaded joint, sealed with an O-ring. The motor case is knurled at the interface contact surface to offset rotational forces that tend to tighten the warhead during gun firing. The warhead is staked to the motor case to preclude loosening as a result of rough handling.

WARHEAD

The Mk 74 5"/38 warhead, developed and released by Naval Weapons Laboratory, Dahlgren, Virginia (NWL/D), is 9 inches long and weighs 21.0 pounds when loaded (pressed) with 3.3 pounds of Composition A-3 explosive. The warhead case weight is 17.7 pounds. Case material is a brittle steel (AISI-06, relaxed specifications) having a hardness of R_c 28-36 and approximately 100,000 psi minimum yield strength. The explosive is press loaded then bored to accept a Mk 1 fuze cavity liner.

FUZE

The RAP test specimens were configured with Mk 29 Mod 3 PD fuzes or Mk 357 Mod 0 CVT Fuze and Adapter Assemblies. The Mk 29, used in combination with Mk 52 or 43 auxiliary detonating (AD) fuzes, is an in-service fuze, having been tested on and released for use with standard 5"/38 projectiles. Pellets of Composition A-3 explosive are used to fill the cavity space resulting from the varied AD fuze lengths. The Mk 357 Mod 0 Fuze and Adapter Assembly is an adapted Army M514 CVT fuze, which is also released for use on standard Navy projectiles. This fuze has a variable-time-setting capability of 5 to 100 seconds with PD backup or it can be set for PD only.

ROCKET MOTOR

The rocket motor, Mk 62 Mod 0, is a short-duration, high-thrust unit with delayed ignition. The motor is 10.0 inches long, weighs 30.2 pounds, and contains a solid-propellant grain, a graphite nozzle insert, and a delay igniter. Silicone rubber pads separate grain segments and cushion the grain at both ends. A glass cloth-phenolic resin end plate at the forward end protects the warhead from the gas vortex action during motor operation.

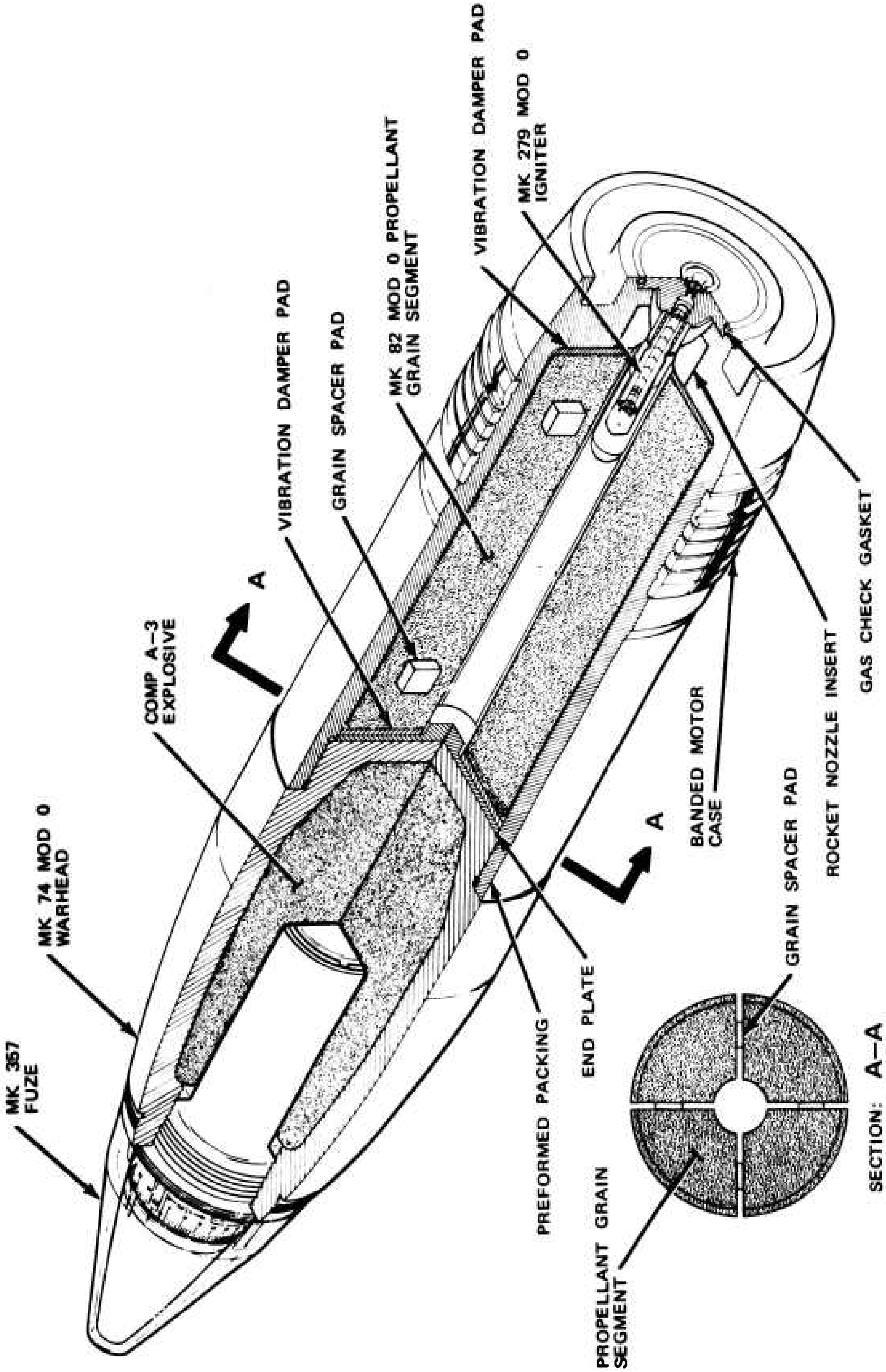

FIG. 1. Mk 57 Mod 0 RAP.

Motor Case

The motor case is an integral unit of 4340 steel heat treated to 200,000 - 220,000 psi u.t.s. and is affixed with a copper rotating band to impart stabilizing spin. Motor case weight is 22.1 pounds.

Propellant

The propellant is a 20%-aluminum fluorocarbon formulation, N-34, with high density-impulse characteristics and the high physical strength required to withstand the 18,000 g axial and 15,000 g radial acceleration during launch. Propellant formulation and characteristics are given in TP 4555[3]. The propulsive unit is comprised of four Mk 82 Mod 0 Grain Segments with a total propellant weight of 7.1 pounds. Each segment is one quarter of an ext[illegible]ylinder that is 8.200 inches long, 4.085 inches in diameter, and has [illegible]nch-diameter center bore. Each segment is inhibited on the outside diameter with a 0.005- to 0.015-inch-thick coat of RTV silicone rubber applied over a thin coat of silicone resin primer.

Igniter

All D-17 and T-5 test projectiles were configured with the gun gas triggered, percussion-actuated Mk 279 Mod 0 Delay Igniter (Fig. 2), which is sealed into the motor case base with a gas check gasket and is blown out at motor ignition. Gun gas pressure flexes a spring disk that strikes a No. 34 percussion primer, which, in turn, initiates the 23-second pyrotechnic delay column. The delay column consists of an initiation charge of A-1A powder, seven pressed increments of TU-3 delay mix (tungsten, barium chromate, and potassium perchlorate, 20 sec/in. burn rate), and an output charge of pressed boron potassium nitrate. The ignition charge, ignited by the delay column output charge, is 4 grams of magnesium-Teflon pellets.

The Mk 279 Mod 1 igniter, developed after completion of Tests D-17 and T-5, is similar to the Mod 0, using the same delay column and ignition charge. The Mod 1 differs from the Mod 0 in the housing, retainer, spring disk, and primer. To increase reliability, the No. 34 primer was replaced with the more sensitive M-35 primer and the spring disk thickness was reduced to 0.015 inch. The housing was modified to place the primer closer to the spring, optimizing the force with which the spring strikes the primer. By structurally improving the retainer, the safe drop height (onto a 3/4-inch-diameter protrusion) was increased to 3 feet.

[3]Naval Weapons Center, N-34 Propellant Characterization (U), by George C. Van Deusen, China Lake, Calif., NWC, November 1968. (NWC TP 4555), CONFIDENTIAL.

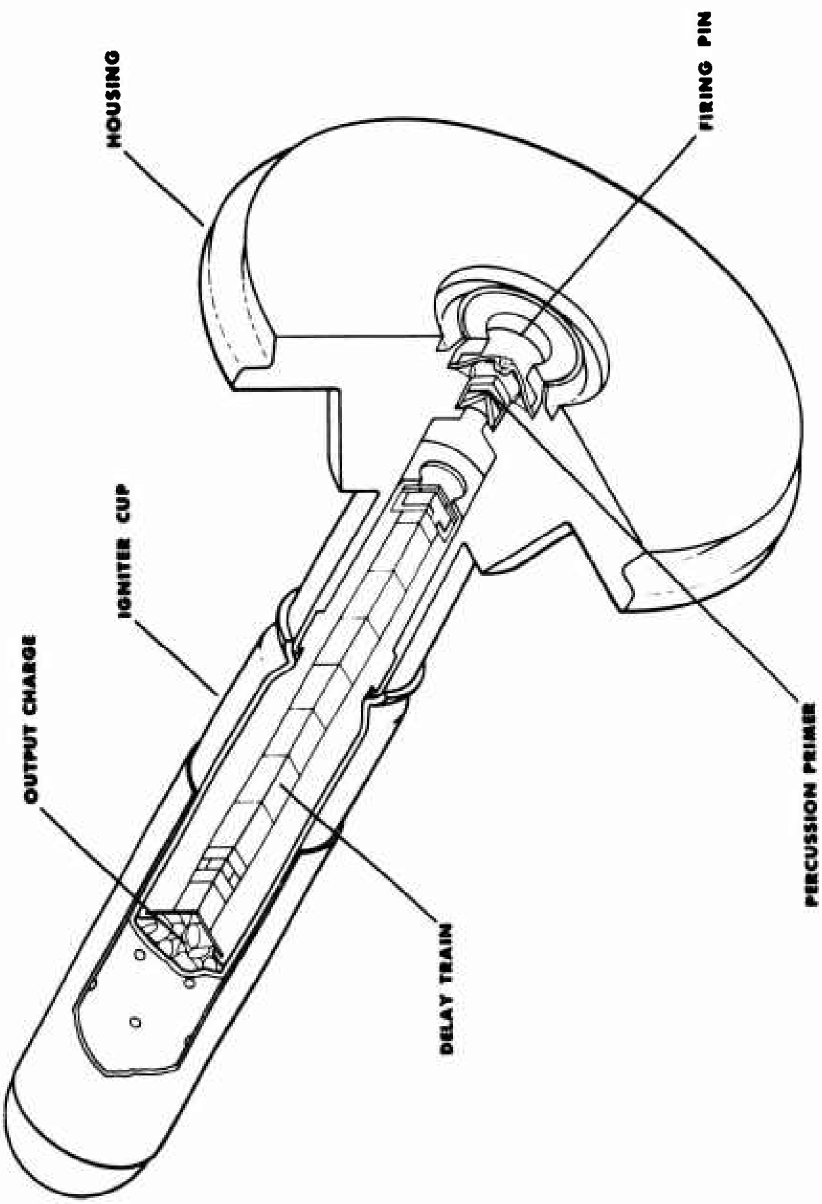

FIG. 2. Mk 279 Mod 0 Igniter.

Empty Parts

Major empty parts, in addition to the motor case, consist of a nozzle insert, grain spacer pads, vibration damper pads, and an end plate.

The nozzle is an ATJ grade graphite insert that is bonded into a recess in the motor case. The insert has a contoured exit cone and a 0.718-inch-diameter throat designed for motor operation at 1,200 psi.

The grain spacer pads and vibration damper pads are of silicone rubber. The grain spacer pads are 1/2 inch square by 1/4 inch thick and are used to cushion the segments during transportation and to separate the segments for maintenance of a constant ignition surface area. Each motor contains eight pads, two bonded to each segment. Two vibration dampers, one at each end of the grain segments, provide protection during transportation and firing setback. The dampers are 1/8 inch thick and are "donut" shaped with a 4.000-inch outside diameter and a 1.500-inch inside diameter.

The end plate is required to prevent the gas vortex action from drilling through the warhead base. End plate material is glass cloth impregnated with phenolic resin. The center portion upon which the vortex impinges is 0.850 inch in diameter by 0.375 inch thick.

MANDATORY TESTS

ENVIRONMENTAL SEQUENCE

Nine all-up RAP (TM-1C, -2C, -3C for D-17, TM-13F through TM-18F for T-5) were subjected to environmental sequence tests consisting of temperature/humidity treatment, vibration, and 40-foot drop. The D-17 RAP had CVT fuzes, the T-5 RAP had three each of PD and CVT fuzes.

Temperature/Humidity

Temperature/humidity tests for D-17 were conducted at NWC. T-5 tests were accomplished by Ogden Technology Laboratories, Beaumont, California, under contract N60530-68-C-0691 issued by NWC.

Upon receipt at the test facilities, all projectiles were visually examined for evidence of damage during transportation. There was no evident damage. The projectiles, with fuze caps and rotating band protectors installed, were placed on wooden support fixtures in the test chambers.

The D-17 projectiles were subjected to six cycles of treatment, with each cycle consisting of 24 hours at -65°F and 24 hours at 165°F and 95% relative humidity (165°F/95% RH). A malfunction of the conditioning unit, 5 hours into the first period at 165°F/95% RH, allowed the chamber temperature to rise to 180°F, which existed for 13 hours 30 minutes. The projectiles were then returned to ambient and radiographically inspected; no anomolies were noted. T-5 treatment consisted of 10 cycles, with each cycle consisting of 12 hours at each temperature.

Post-test inspection revealed the amount of discoloration and rust deposits normally found after temperature/humidity treatment. Exceptions occurred on TM-2C and TM-3C, which had deposits of what appeared to be explosive binder in the fuze area. TM-2C had a deposit 1 1/2 inches square by 1/4 inch high inside the fuze protector cap and a smaller deposit inside the fuze windshield. On TM-3C, a deposit 1 by 2 1/2 inches was observed near the base of the fuze windshield. An analysis revealed that the deposits were wax from the Composition A-3. There was no trace of explosive (RDX).

Transportation Vibration

Following temperature/humidity, the projectiles were subjected to transportation vibration per MIL-STD-810B along three mutually perpendicular axes at two temperatures (-20, 125°F) for each axis. Vibration per MIL-STD-167 (SHIPS) is called out in WR-50; however, inputs from MIL-STD-810B were selected because they were much more severe in amplitude and covered a broader frequency range. For D-17, each vibration period consisted of 1 1/2 frequency sweeps covering the frequency range of 5 to 500 to 5 Hz in 15 minutes (total vibration time of 22.5 minutes). For T-5, the maximum frequency was reduced to 50 Hz because the D-17 projectiles (55 pounds each) were treated individually, whereas the T-5 projectiles were placed in a fixture (12 projectiles totaling 660 pounds) designed to simulate the pallet adapter in which the projectiles are normally transported. MIL-STD-810B requires a maximum frequency of only 50 Hz for test items weighing 500 pounds or over. Excitation input levels were 1.3 *g* vector from 5 to 26 Hz, 0.036-inch double amplitude from 27 to 52 Hz, and 5 *g* vector from 53 to 500 Hz.

All projectiles received a minimum of 2 hours 15 minutes of vibration (six periods of 22.5 minutes each). In addition, a 15-minute dwell was conducted at each resonant frequency (encountered only in D-17). Table 2 contains resonant frequencies and total vibration times for D-17 and T-5.

TABLE 2. Resonant Frequencies and Total Vibration Time.

Projectile	Temp, °F	Axis[a]	Resonance, Hz	Total vibration time
TM-1C	-20	T	320	3 hr 15 min
	-20	V	318	
	125	T	500	
	125	V	345	
TM-2C	-20	T	349	3 hr
	-20	V	342	
	125	V	321	
TM-3C	-20	T	322	3 hr 15 min
	-20	V	282	
	125	T	352	
	125	V	350-380	
TM-13F through TM-18F			None	2 hr 15 min each

[a]T - Transverse.
V - Vertical.

Post-test inspection revealed several cracks in the forward end of the CVT fuze windshield on TM-2C. The fuze protector cap on TM-1C showed evidence of contact with the windshield as indicated by polished areas on the inside of the protector cap. The windshield had a 3/4-inch-long crack at the forward end. Although the cause of the cracks was not established, a strong possibility existed that the windshields came into contact with wet paint, which set up stress points in the lexan windshield. The T-5 projectiles (TM-13F through TM-18F) had loose fuze caps on three projectiles and a moderate amount of scratches and chipped paint.

Forty-Foot Drop

Each projectile was affixed with a split-ring harness positioned to assure that upon release the projectile would impact in the intended attitude. The harness was then attached, by means of a circular steel ring connected to the harness assembly, to a bomb shackle release mechanism. After being raised to 40 feet, the projectiles were released to impact a steel plate imbedded in 2 feet of concrete. Drop attitudes were as follows:

1. Horizontal - TM-1C, TM-15F, TM-18F
2. Base down - TM-2C, TM-14F, TM-17F
3. Nose down - TM-3C, TM-13F, TM-16F

None of the projectiles detonated or deflagrated. All were considered by the Explosive Ordnance Disposal Team to be safe-to-handle for disposal by qualified personnel. An example of the fuze damage incurred on nose-down drops is shown in Fig. 3, a post-drop view of a projectile with a CVT fuze. Damage to the projectile body was most severe on horizontal drops, but was minor in all cases.

FIG. 3. View of CVT-Fuzed Projectile After Nose-Down 40-Foot Drop (LHL 142878).

FAST COOKOFF

Two CVT-fuzed projectiles, one PD-fuzed projectile, one rocket motor, and one warhead were subjected to a fast cookoff test (enveloping flame). Each test specimen was instrumented with several chromel alumel (Type K) thermocouples, located both externally and internally at the explosive/case interface, and placed in a steel restraining cage that was suspended 3 feet above a fuel pan containing 350 gallons of water and 400 gallons of 115/145 octane aviation fuel. The restraining cage was utilized to prevent projectile launch in the event of rocket motor ignition prior to warhead detonation.

The criterion by which a warhead is judged to have passed the fast cookoff test is that burning, deflagration, or detonation of the explosive load shall not have occurred at an explosive/case interface temperature of less than 300°F. The rocket motor has no fast cookoff requirement.

D-17 included only one fast cookoff test, a CVT-fuzed projectile, TM-7C. The projectile warhead detonated low order 3 minutes 15 seconds after ignition of the fuel, destroying the restraining cage. The rocket motor fell from the cage into the fuel pan, and submerged beneath the fuel and water. Two warhead fragments penetrated the bottom of the fuel pan permitting the water to run out of the pan. As the water level decreased, the fuel level also decreased to a point where the rocket motor was exposed. The flames then ignited the propellant at approximately 19 minutes after fuel ignition. The motor burned for 1 minute, completely consuming the propellant. The gasoline burned for 20 minutes 30 seconds. Due to instrumentation problems at the test site, the thermocouple data were adjudged invalid. Figure 4 is a post-test view of the test site showing the fuel pan with the expended rocket motor case.

T-5 fast cookoff tests were conducted on a PD-fuzed projectile (TM-26F), a CVT-fuzed projectile (TM-27F), a rocket motor (TM-28F), and a warhead (TM-29F). All units were instrumented with Type K thermocouples, but as in D-17, the data received were invalid. A test setup similar to that used in D-17 was used to test each unit separately. Results were as follows:

1. TM-26F - A high-order warhead reaction occurred 3 minutes 55 seconds after ignition of the fuel. The detonation completely destroyed the restraining cage and ruptured the fuel pan in several places. The rocket motor base and a 2 1/4- by 1 1/4-inch motor case fragment were found 165 feet from ground zero. Another motor case fragment 3 by 4 inches was found 153 feet from ground zero. Portions of the fuze were found at 50 feet and the fuze adapter at 188 feet. Several smaller projectile fragments were found at various distances. Figure 5 shows the recovered fragments.

FIG. 4. Post-Test View of Fast Cookoff Test Site, TM-7C. A low-order warhead reaction destroyed the restraining cage, dropping the rocket motor into the fuel, where it ignited when the fuel burned down to the level of the motor.

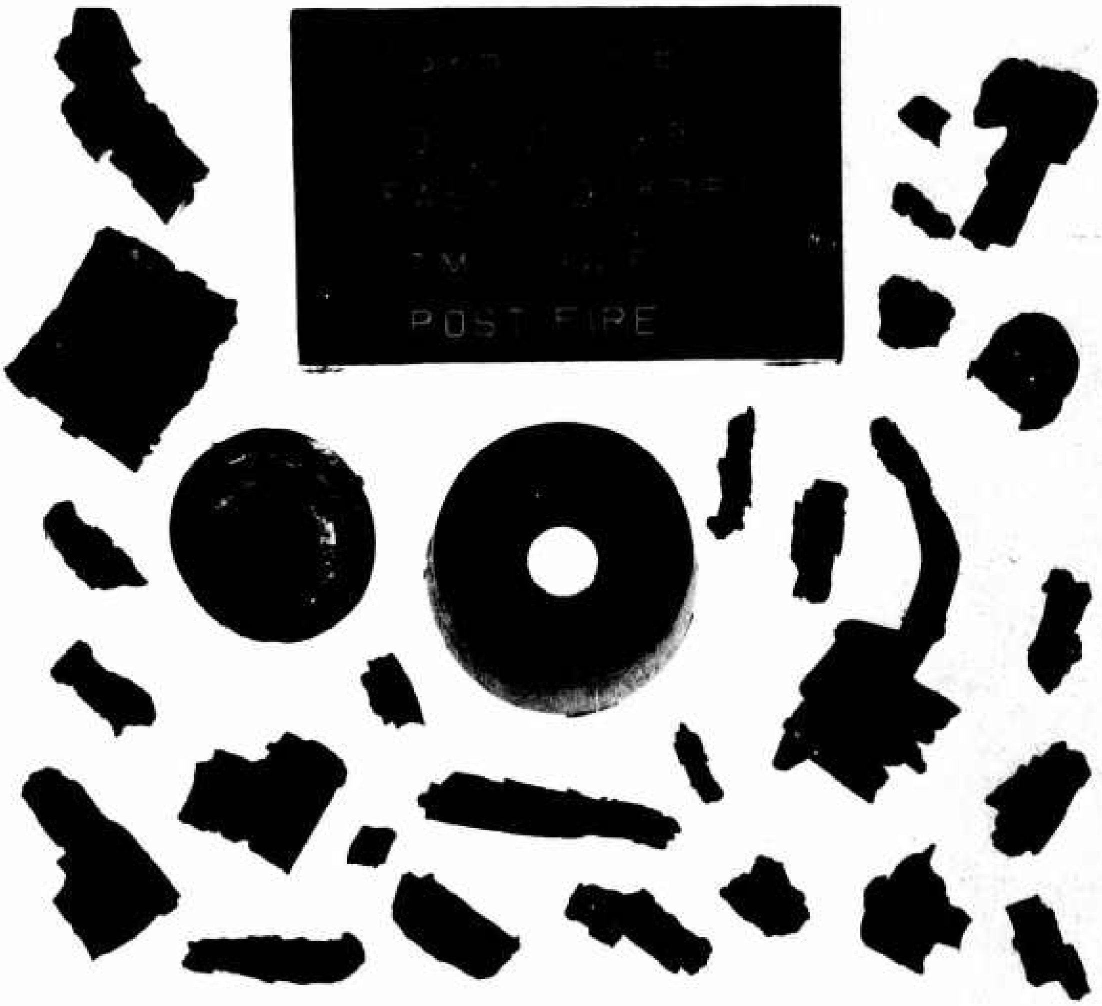

FIG. 5. Recovered Fragments From TM-26F High-Order Detonation. The two circular pieces are the fuze adapter (left) and the rocket motor base (right) (LHL 142865).

2. TM-27F - A high-order warhead reaction occurred 2 minutes 40 seconds after ignition of the fuel. The size and location of the recovered fragments was similar to that of TM-26F (Fig. 5).

3. TM-28F - Rocket motor ignition occurred 5 minutes 50 seconds after fuel ignition. All gases exhausted from the forward end since the plastic shipping plug had melted at a lower temperature. The igniter remained in the base, although all ordnance items in the igniter burned.

4. TM-29F - The warhead detonated 5 minutes 45 seconds after fuel ignition. Although the restraining cage was severely damaged, fragment recovery indicated a low-order reaction. A fragment 9 1/4 by 3 3/4 inches was recovered at ground zero, a fragment 7 7/8 by 2 inches was recovered 54 feet from ground zero, and a third, 6 1/2 by 1 3/4 inches, was recovered at 24 feet.

SLOW COOKOFF

Two CVT-fuzed projectiles, one PD-fuzed projectile, one rocket motor, and one warhead were subjected to slow cookoff tests. Each test specimen was instrumented with several Type K or iron constantin (Type J) thermocouples and placed in an insulated oven. The ovens were 36 inches long by 6 inches in diameter, except for the warhead cookoff oven, which was 25 inches long. The ovens were buried in pits and covered with 1 foot of earth (6 inches for the warhead). After 8 hours of conditioning at 225°F, the oven controls were set for a linear temperature rise of 6°F/hr until destruction of the test specimen.

Warhead criterion for passing a slow cookoff test is the same as for a fast cookoff, no violent reaction at an explosive/case interface temperature of less than 300°F. Although the rocket motor specification lists no slow cookoff requirement, it does impose an autoignition requirement that the motor and igniter shall withstand 350°F for a minimum of 2 hours.

D-17 included only one slow cookoff test, a CVT-fuzed projectile, TM-6C. Cookoff occurred 22 hours 16 minutes after the temperature rise was initiated. At the time of reaction, the temperatures recorded by the thermocouples were

1. Projectile surface - 342°F average
2. Warhead explosive/case interface - 350°F maximum
3. Motor propellant/case interface - 338°F maximum

Recovery of fragments found in the cratered area and scattered over a wide area around ground zero indicated that a high-order detonation had occurred.

T-5 slow cookoff tests were conducted with a PD-fuzed projectile (TM-22F), a CVT-fuzed projectile (TM-23F), a rocket motor (TM-24F), and a warhead (TM-29F). Results were as follows:

1. TM-22F - A high-order warhead reaction occurred 21 hours 58 minutes after the 6°F/hr temperature rise was initiated. At the time of cookoff, the temperature readings were

   a. Projectile surface - 349°F average
   b. Warhead explosive/case interface - no data
   c. Rocket propellant/case interface - 347°F maximum

Inspection of the test site revealed several large fragments of rocket motor case with pieces of propellant attached. Figure 6 shows the recovered fragments.

FIG. 6. TM-22F After Slow Cookoff Showing Recovered Projectile Pieces, Oven Parts, and Scraps of Unburned Propellant. The warhead detonated high order.

2. TM-23F - A high-order warhead reaction occurred 20 hours 35 minutes after the temperature rise was initiated. At the time of cookoff temperature readings were

a. Projectile surface - 343°F average
b. Warhead explosive/case interface - no data
c. Rocket propellant/case interface - 348°F maximum

The reaction created a crater 8 feet in diameter by 4 feet deep and hurled a portion of the cookoff oven 294 feet. A search of the cratered area and surrounding test area revealed only a few small fragments.

3. TM-24F - Rocket motor reaction occurred 34 hours 26 minutes after the temperature rise was initiated. At the time of cookoff, the motor had a maximum propellant/case interface temperature of 463°F and an average surface temperature of 434°F. Inspection of the test site showed that no violent reaction had taken place. Removal of the cookoff oven from the trench revealed that the rocket motor had ignited, melting the plastic shipping plug and slightly bulging the forward section of the case. The igniter assembly was still intact in the base of the motor. All propellant and igniter mix were consumed.

4. TM-25F - A high-order warhead reaction occurred 20 hours 21 minutes after the temperature rise was initiated. At the time of cookoff, the warhead had a maximum explosive/case interface temperature of 353°F and an average surface temperature of 348°F. Inspection of the test site revealed that a violent reaction had occurred and only a few small warhead fragments were recovered.

20 MM BULLET IMPACT

Six all-up rounds (three each CVT- and PD-fuzed) were subjected to 20 mm bullet impact tests. Two of each type were impacted in the warhead, one of each was impacted in the rocket motor. Each projectile, strapped in a test fixture to prevent it from toppling, was impacted by a 20 mm M95 AP nonincendiary projectile. The 20 mm barrel was positioned 300 feet from the RAP target and imparted an initial velocity of 2,700 $\pm$100 ft/sec to the M95 projectile.

The criterion by which an item is judged to have withstood the bullet impact test is that no violent explosive reaction such as a detonation or deflagration shall have been produced.

Rocket Motor Impact

Projectile TM-4C (D-17) and TM-31F (T-5) were impacted in the rocket motor. The T-5 test plan originally called for TM-20F to be impacted in the motor; however, missighting and sudden wind gusts caused the 20 mm projectile to impact the warhead. As a result, TM-31F, which had been

used in the rocket motor blast test, was reused for the 20 mm bullet impact. TM-31F had received damage only to the fuze protector cap during rocket motor blast and was considered acceptable for the bullet impact test.

TM-4C was impacted in the center of the motor 5 7/8 inches from the base. Upon impact, the propellant ignited, causing the warhead to be separated and propelled from the rocket motor assembly. The warhead/fuze assembly was found 192 feet from ground zero and showed no visible signs of damage. The rocket motor propellant was completely consumed and the case slipped from the fixture, coming to rest 56 inches from ground zero. There was no evidence of an exit hole from the 20 mm projectile in the motor case. Figure 7 is a close-up view of the motor case showing the residue from the burnt propellant and the penetration hole of the 20 mm round.

FIG. 7. View of TM-4C Motor Case After 20 mm Bullet Impact. The warhead separated from the motor, but was not damaged. The 20 mm projectile remained in the motor and all propellant was consumed.

On TM-31F, the 20 mm projectile impacted and passed completely through the rocket motor at the center and 5 inches from the base. No explosive reaction was evident. The force of the impact was sufficient to separate the warhead and rotating band from the rocket motor case. The rotating band and warhead were found 66 and 33 feet from ground zero, respectively. The base of the rocket motor case was sheared from the case and part of the base remained at ground zero. The remaining portions of the rocket motor case and the rocket motor propellant were found in an area 30 feet from ground zero. The igniter was separated from the igniter housing but was found intact with no evidence of having functioned. Examination of the recovered propellant indicated that ignition of the grain had not occurred.

Warhead Impact

Projectiles TM-5C (D-17) and TM-19F through TM-21F (T-5) were impacted in the warhead. The test sequence for T-5 was TM-19F, TM-21F, and TM-20F.

The first 20 mm round fired at TM-5C impacted the center of the projectile in the warhead/motor joint and failed to contact the explosive charge. The projectile penetrated the case for only about one-half the projectile's length. There was no detonation or deflagration as a result of this impact. The second round impacted the right side of the warhead case, causing a small flash and exposing the explosive charge. The third round penetrated the warhead 1 inch left of center and 15 1/2 inches from the base of the projectile. Upon impact the explosive charge ignited and burned for 7 minutes, at which time the auxiliary detonator exploded. After consumption of the explosive charge, the projectile was still supported by the test fixture and the rocket motor was intact. There was no exudation or burning of the propellant. Figure 8 is a post-test view of projectile TM-5C.

Projectile TM-19F was impacted in the warhead 1 1/4 inches to the left of center and 13 inches above the base of the rocket motor. A segment of the warhead case, approximately 6 1/4 inches by 4 inches, was separated from the warhead's aft side in relation to the entrance of the 20 mm round, and was found 60 feet from ground zero of the target area. The fuze protector cap was recovered 27 feet from ground zero and contained a 5 1/4-inch split on one side. The PD fuze was separated from the projectile and was found 21 feet from ground zero. Shattered explosive fragments were found strewn around the test area at various distances and were recovered. A small flash was observed upon impact of the 20 mm round but there was no visible evidence of ignition of the explosive. Figure 9 is a view of some of the recovered parts of the projectile; however, the aft section of the warhead case was not included in this photograph.

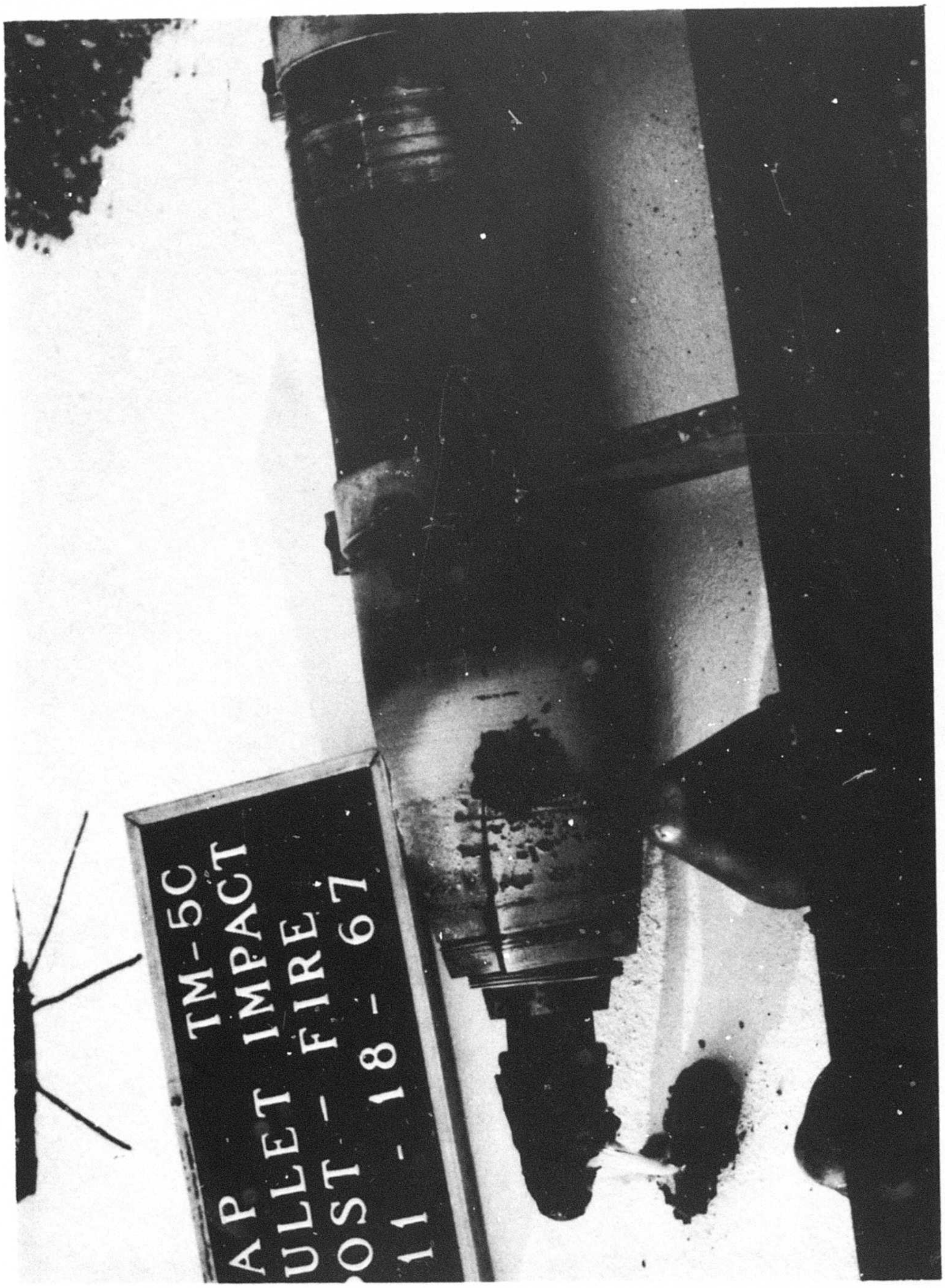

FIG. 8. Post-Test View of Projectile TM-5C. Two 20 mm bullet impacts, in the warhead/motor joint and a "nick" on the side, caused no reaction. The third resulted in burning of the explosive.

FIG. 9. Recovered Parts of TM-19F, Impacted in Warhead by 20 mm Projectile. The warhead incurred a pressure rupture, but no violent reaction occurred (LHL 142848).

Projectile TM-21F was impacted in the warhead 1/2 inch to the left of center and 18 1/2 inches from the base of the rocket motor in the area of the booster of the auxiliary detonator. The 20 mm round remained in the warhead. There was no evidence of explosive ignition. The fuze protector cap split in the threaded area and was found 66 feet from ground zero. The fuze shattered into several segments with the largest being found 6 feet from ground zero. A 2 3/4- by 3/4-inch fragment of the fuze adapter was found 21 feet from ground zero. There was a "U" shaped crack on the exit side of the warhead case in reference with the entrance of the 20 mm round.

Projectile TM-20F incurred a low-order detonation when impacted in the warhead. One fragment of the warhead, 5 1/4 by 2 1/8 inches, was recovered 138 feet from ground zero. Smaller fragments of the warhead were found at various distances from ground zero. The warhead fuze was destroyed by the detonation of the warhead. The rocket motor case, recovered 30 feet from ground zero, was bulged at the warhead/motor interface, but intact. Approximately 80% of the rocket motor propellant was found within 142 feet of ground zero. Visual examination of the propellant segments indicated that a partial burn had occurred.

The low-order detonation incurred by TM-20F and the deflagration of TM-4C and TM-5C were not in accordance with WR-50, which required that no violent reaction occur. This failure to meet WR-50 passing criterion was unexpected as the RAP warhead was quite similar to some in-service 5"/38 standard projectiles (e.g., both used Composition A-3 explosive). However, no data existed concerning standard projectile sensitivity to bullet impact since the in-service projectiles were developed and introduced into the Fleet prior to the existence of WR-50. Therefore, a test series was conducted to evaluate standard projectile reaction to 20 mm bullet impact. Eight projectiles (four each 5"/38 Mk 49 and 5"/54 Mk 41) loaded with Composition A-3 were subjected to bullet impact to obtain comparative data. The results (Appendix) showed that RAP was comparable to the in-service projectiles. Only two of the eight test units (5"/38 Mk 49 projectiles) met the WR-50 passing criterion of no violent reaction. One Mk 49 incurred a low-order detonation; the remaining Mk 49 and all four 5"/54 Mk 41 projectiles deflagrated. It was therefore concluded that, although RAP did not pass WR-50, RAP was acceptable on the basis that it was no more hazardous than the standard in-service projectiles.

OPTIONAL TESTS

WR-50 lists several optional tests, the applicability of which is left to the discretion of the Naval Ordnance Systems Command. It was determined that two tests, rocket motor blast and propagation, were applicable to RAP. The propagation test was then refined into two separate tests, adjacent detonation (D-17) and propagation (T-5).

ADJACENT DETONATION

The adjacent detonation test was conducted with TM-8C (acceptor) and a 5"/54 AAC Mk 41 Mod 0 projectile (donor) loaded with explosive D. The donor and acceptor projectiles were placed in a vertical position, fuze uppermost, 1 foot apart. After the fuzing was removed from the donor projectile, the fuze cavity was filled with Composition C-3 explosive and a 1-inch-diameter by 1 1/4-inch-long tetryl booster pellet to the level of the explosive D. An HC-37 detonator, initiated with 117 vac, was used to detonate the donor projectile.

Upon initiation of the donor, the acceptor projectile was propelled 147 feet from ground zero by the force of the detonation. The Mk 357 CVT fuze, rotating band, and the rocket motor igniter were separated from the projectile. Parts of the igniter and fuze were found on and close to ground zero. The motor and warhead were intact with the exception of a 1- by 2 1/4- by 3-inch-deep fragment hole located 9 inches from the base of the projectile. There was no reaction of either the explosive or propellant of the acceptor projectile.

PROPAGATION

A total of 12 projectiles, TM-1F through TM-12F, were used for the propagation test. The purpose of the test was to evaluate the effects of a 5"/38 RAP warhead detonation under shipboard stowage conditions.

To simulate shipboard stowage, a steel test fixture with a removable front batten was constructed. The test fixture was placed in the center of a modified 5"/38 gun shield to restrain the projectiles in the event of ignition of the rocket motors. The steel front of the gun shield was removed and two layers of heavy-gage cyclone fencing with a securable door was welded in place to permit photographic coverage of the test.

The 12 projectiles were then placed in the test fixture. Upon completion of loading, the fuze protector cap of projectile TM-12, the center projectile in the next to lowermost row, was removed and a 1-inch-diameter by 1-inch-long tetryl booster pellet and an HC-37 detonator placed in the fuze cavity. Figure 10 shows the arrangement of projectiles. The simulated steel batten was then set in place in the test fixture. Figure 11 shows the completed test setup. TM-12F was then detonated by applying a 117 vac pulse to the HC-37 detonator.

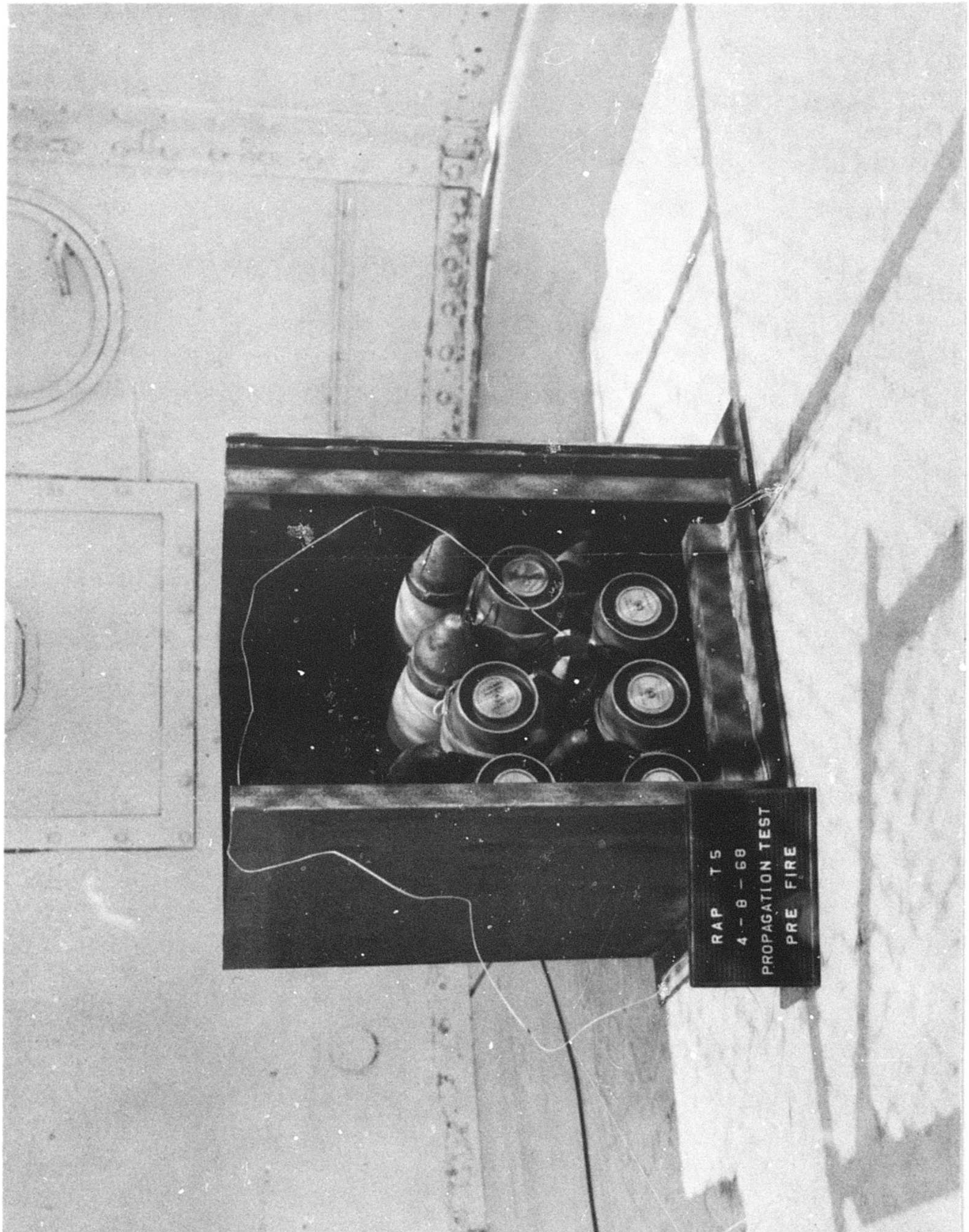

FIG. 10. Projectiles for Propagation Test Installed in Simulated Stowage Bin. The detonator and booster charge are installed in the donor projectile (LHL 142887).

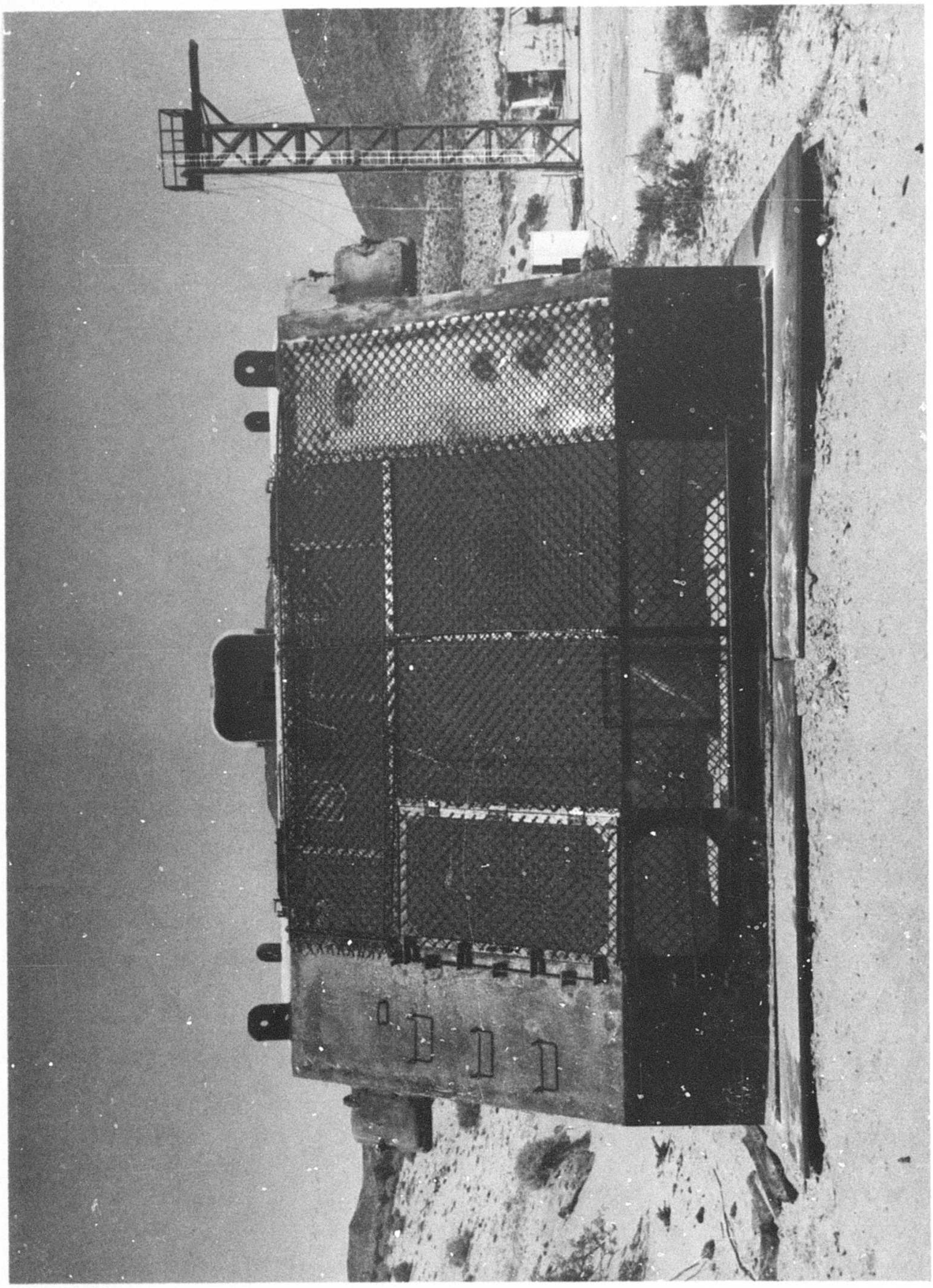

FIG. 11. Completed Setup for Propagation Test Prior to Detonation of Donor Projectile (LHL 142890).

Upon application of the firing pulse, all 12 projectiles appeared to detonate simultaneously. Visual inspection of the test site revealed the following:

1. The 5"/38 gun shield was completely destroyed. The side, front, rear, and top portions were propelled distances of 50 to 125 feet from ground zero. Figure 12 is an overall post-test view of the test site.

2. Fragments of projectiles were recovered from a 360-degree area of approximately an 800-foot radius from ground zero. Inspection of the test area and of the recovered parts indicated that all 12 projectile warheads detonated. Inspection of the fragment size and fragments of unconsumed propellant and explosive indicated that at least three of the projectile warheads experienced low-order detonations. It was estimated that the other nine projectiles experienced high-order detonations.

ROCKET MOTOR BLAST

A total of five all-up projectiles, TM-30F through TM-34F, and two unfuzed projectiles with inert warheads and live rocket motors, TM-35F and TM-36F, were utilized in a series of rocket motor blast tests. The tests were designed to evaluate the effects of accidental ignition of a RAP projectile in shipboard stowage. The test series was conducted in three arrangements to determine the effect of the rocket motor flame impinging upon adjacent projectiles in different positions.

Test Position 1 was to simulate the effects of the flame impinging upon a standard batten or bulkhead in shipboard stowage and reflecting upon adjacent projectiles. Three all-up projectiles, TM-30F, TM-31F, and TM-34F, were utilized for this test. All projectiles were configured with a Mk 357 CVT Fuze and Adapter Assembly. The projectiles were placed in a three-place saddle block fixture welded to a fixed steel plate to prevent movement of the test fixture upon rocket motor ignition. Projectile TM-34F, the donor projectile, was placed in the center position with the base of the motor approximately 1 inch away from the deflector plate. The deflector plate was 1/4-inch mild steel. Projectile TM-30F, an acceptor projectile, was placed in the left outboard position with its base 1 inch from the deflector plate. Projectile TM-31F, also an acceptor, was placed in the right outboard position with the tip of the fuze protector cap 1 inch away from the deflector plate. The distance between the projectiles was 1 1/2 inches. Figure 13 shows the arrangement of projectiles.

Test Position 2 was to simulate the effects of the rocket motor flame impinging directly upon the fuze of an adjacent projectile. Projectile TM-32F, the acceptor, was placed in the aft saddle block of a two-place tandem fixture welded to the steel plate. Projectile TM-35F, the donor, was secured in the forward saddle block with the base of the projectile 1 1/2 inches from the tip of the fuze protector cap of TM-32F (Fig. 14).

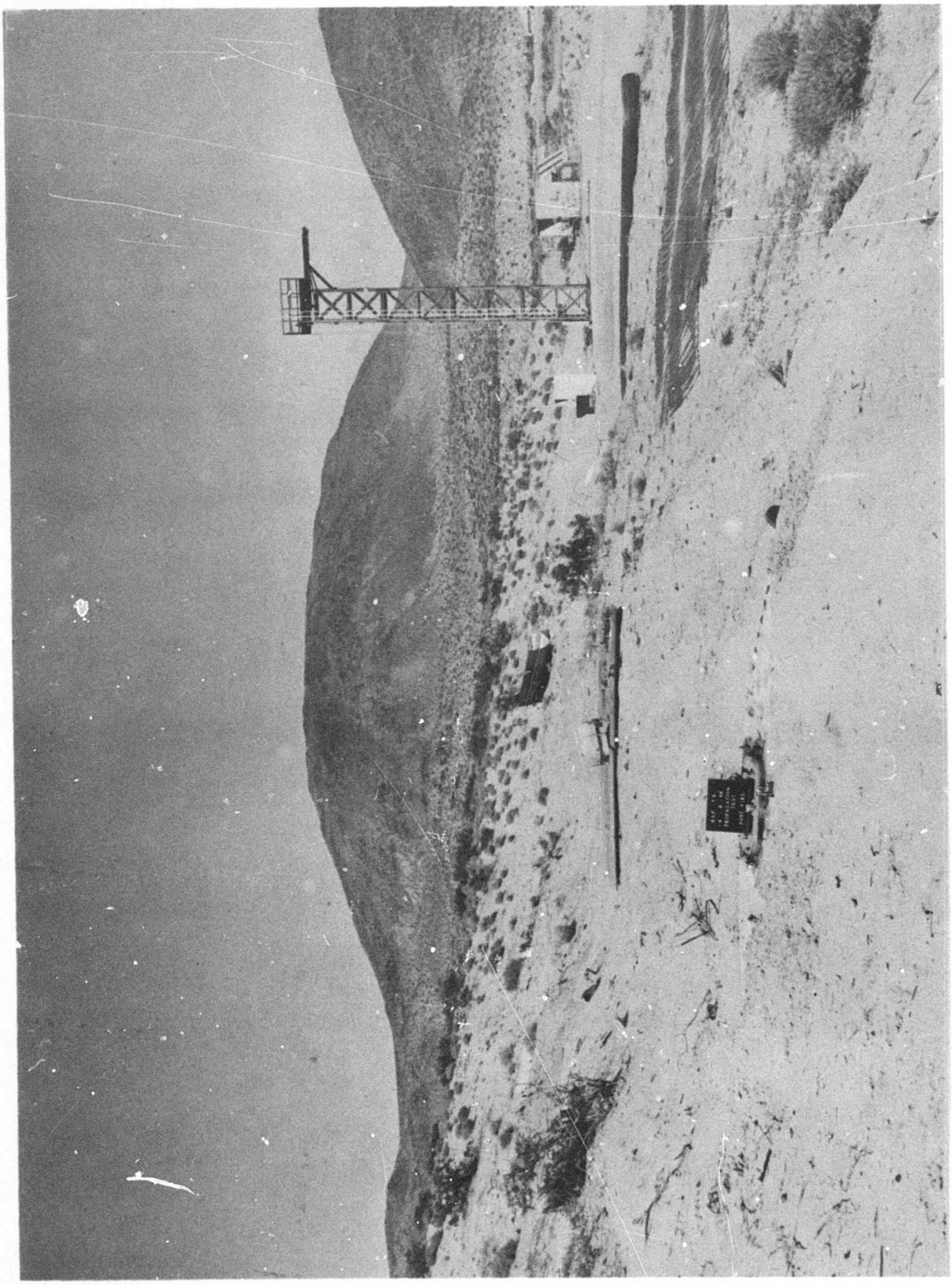

FIG. 12. Post-Test View of Test Site After Detonation of Donor Projectile. The gun shield was completely destroyed by an estimated nine high-order and three low-order simultaneous detonations (LHL 142884).

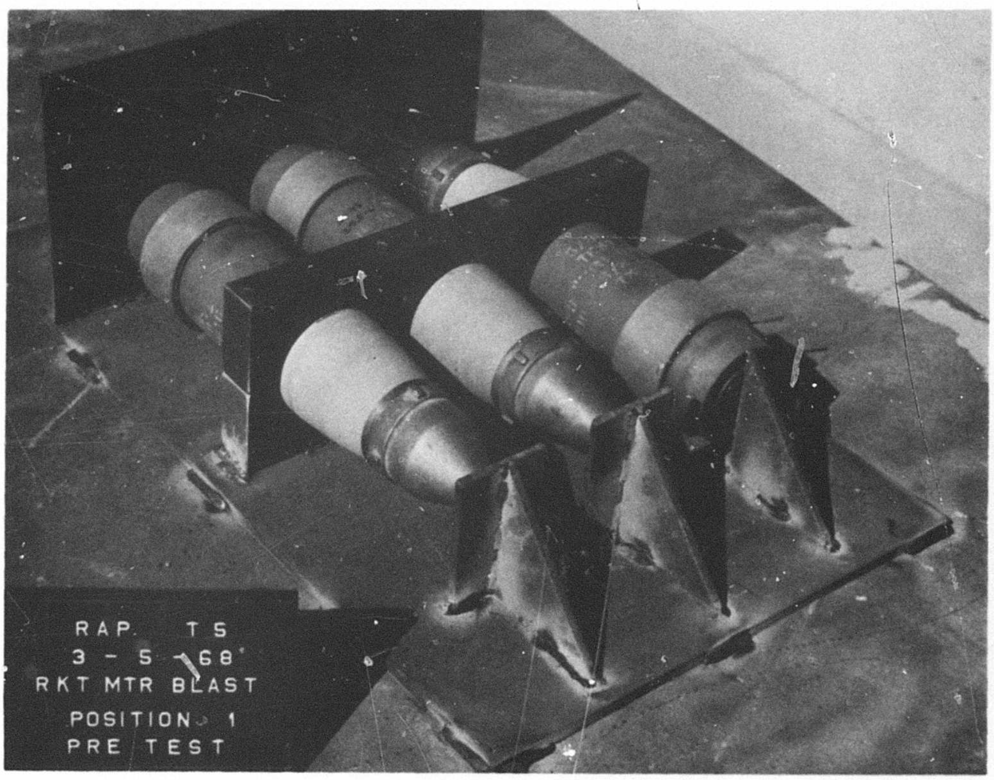

FIG. 13. Setup for Rocket Motor Blast Test, Position 1. The donor projectile is in the center position (LHL 142821).

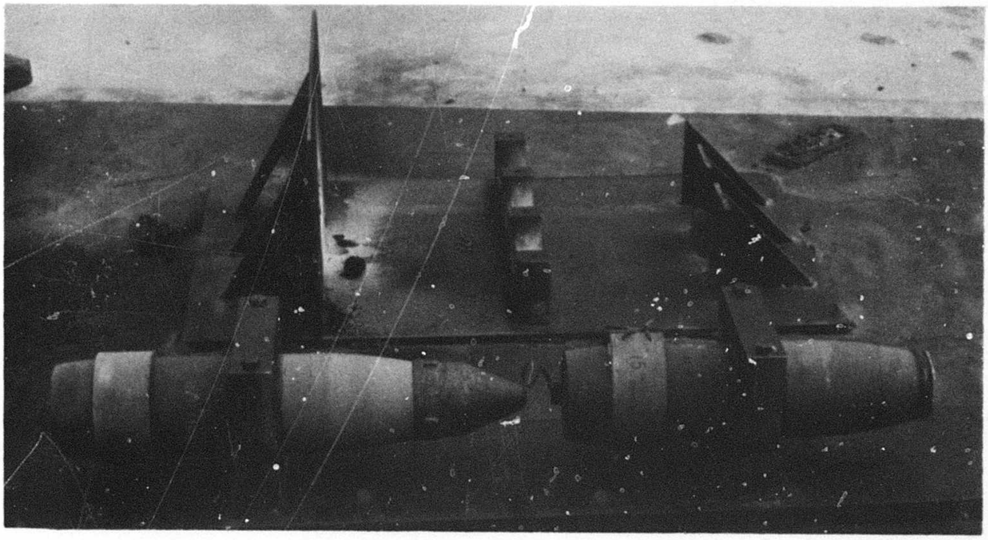

FIG. 14. Setup for Rocket Motor Blast Test, Position 2. The donor projectile is on the right (LHL 142827).

Test Position 3 was to simulate the effects of the rocket motor blast impinging upon the base of an adjacent projectile. Projectile TM-33F, the acceptor, was placed in the forward saddle block of a two-place tandem fixture and projectile TM-36F, the donor, placed in the aft saddle block (Fig. 15). The distance between the bases of the projectiles was 1 1/2 inches.

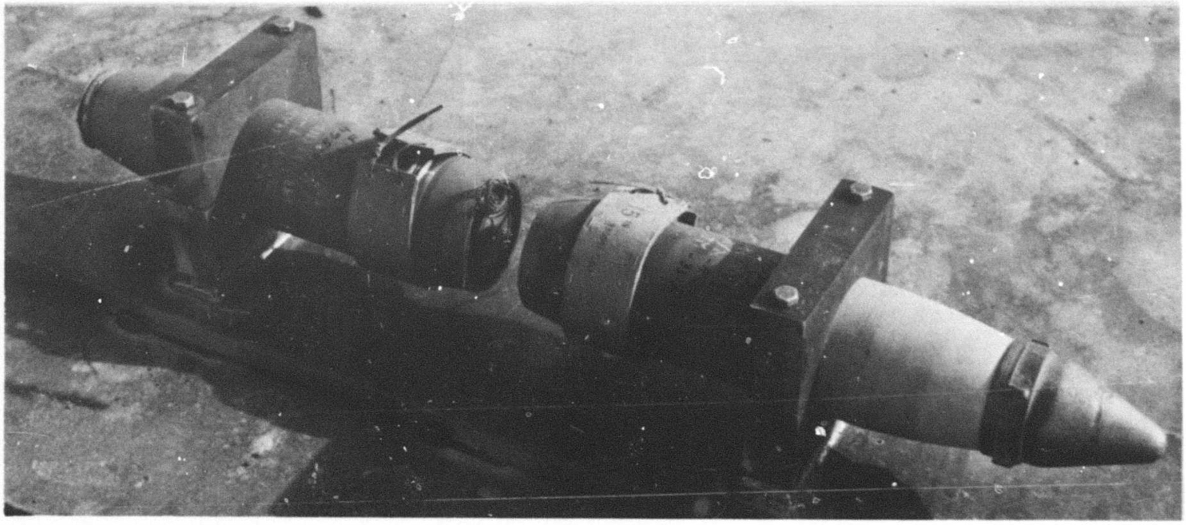

FIG. 15. Setup for Rocket Motor Blast Test, Position 3. The donor projectile is on the left (LHL 142820).

Visual observations during the test and inspection of the test site and items upon the completion of the tests revealed the following:

1. Position 1 - The donor projectile's motor functioned normally and burned for approximately 7 seconds. The donor, TM-34F, moved forward in the saddle block due to the motor thrust and compressed the fuze protector cap approximately 1/4 inch against the forward stop. The rotating band protector was blown off by the motor blast. A hole, 2 1/4 by 3/4 inches, was burned through the simulated bulkhead by the rocket motor flame. One acceptor projectile, TM-31F, suffered a 1/2-inch-diameter burnthrough of the fuze protector cap, but very slight damage to the CVT fuze. The rotating band protector of acceptor projectile TM-30F was blown away as a result of the rocket motor blast and there was a slight discoloration, due to the heat of the motor blast, on the inboard edge of the projectile base.

2. Position 2 - The rocket motor of the donor projectile, TM-35F, functioned normally and burned for approximately 7 seconds, with the flame impinging upon the fuze protector cap of the acceptor, TM-32F, for the full burn period. The fuze protector cap and CVT fuze of the acceptor projectile were burned away back to the point where the fuze protector cap threads engage those of the projectile. There was a slight discoloration on the ogive of the acceptor projectile. Figure 16 is a post-test view of the projectiles.

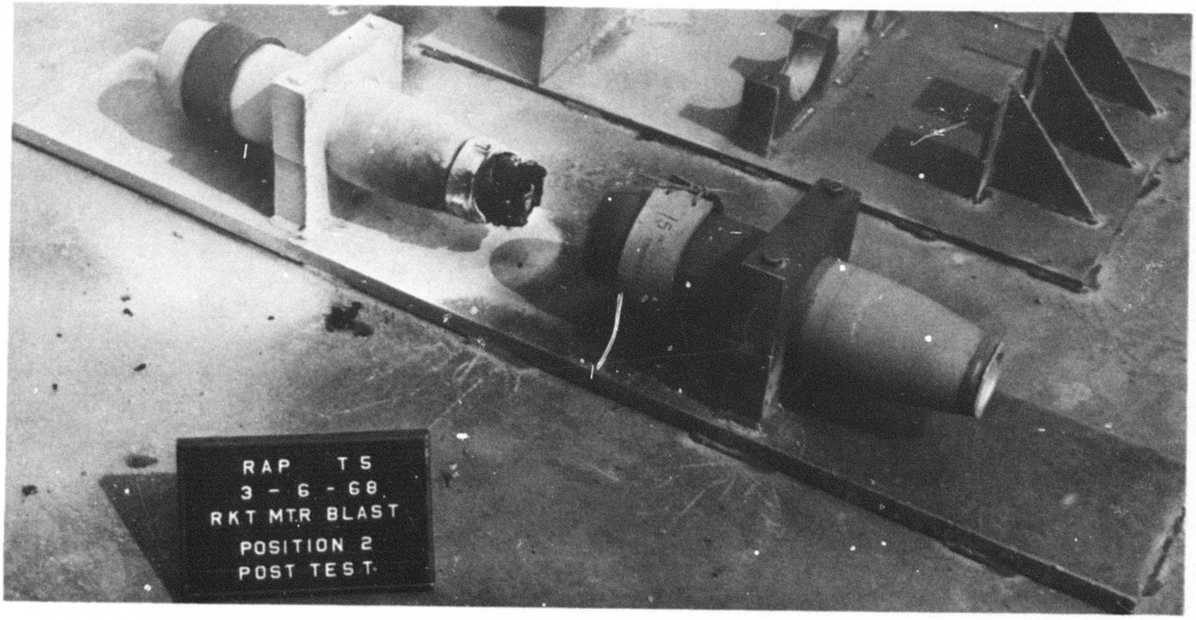

FIG. 16. Post-Test View of Rocket Motor Blast Test, Position 2, Showing Damage to Fuze of Acceptor (Left) (LHL 142833).

3. Position 3 - The donor motor, TM-36F, ignited normally, with the flame impinging on the base of the acceptor projectile, TM-33F. At about 1 second after ignition of the donor rocket motor, the weld holding the saddle block to the plate broke, thereby allowing the donor to launch itself into the hillside 21 feet from ground zero. However, the acceptor projectile remained contained in its saddle block. Approximately 23 seconds after ignition of the donor, which corresponds to the igniter delay time, the acceptor's rocket motor ignited and burned for the normal length of time. Figure 17 is a view of the aft end of the acceptor projectile; erosion from the blast of the donor is evident.

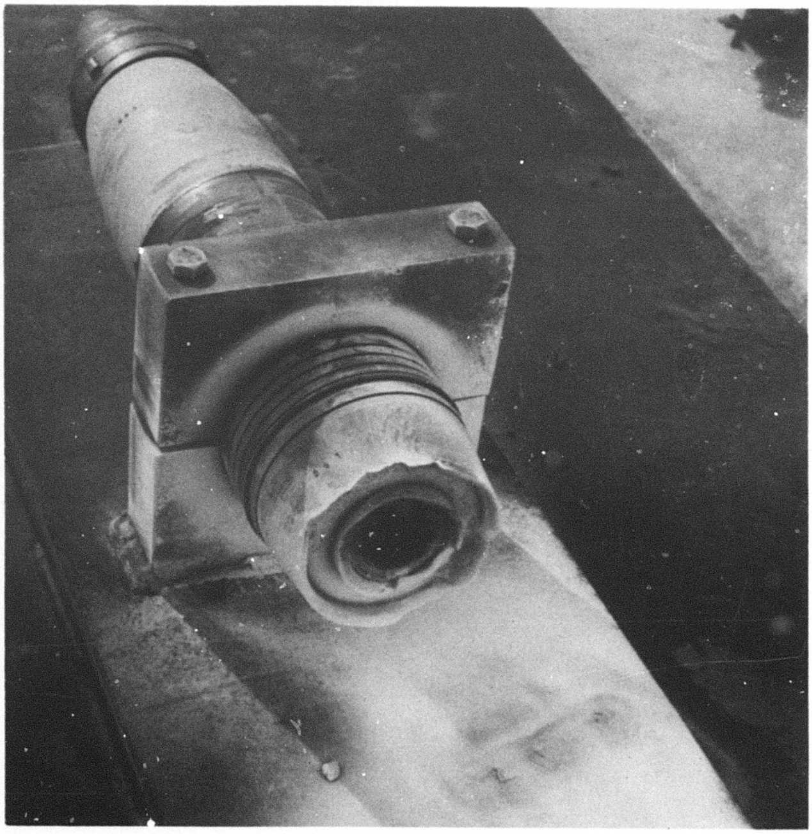

FIG. 17. Post-Test View of Rocket Motor Blast Test, Position 3, Showing Damage to Base of Acceptor. The acceptor ignited after the 23-second delay time (LHL 142831).

ADDITIONAL TESTS

In addition to the mandatory and optional tests listed in WR-50 and MIL-R-23139, several tests were conducted to obtain additional information on RAP safety characteristics. Three areas of investigation were included as part of D-17. They were: unrestrained-projectile ignition, gun muzzle blast, and clearing-charge firing. A fourth area, accidental igniter actuation due to a drop on a raised object, was investigated throughout the igniter development program.

IGNITION OF UNRESTRAINED PROJECTILE

Projectile TM-9C was subjected to an unrestrained-projectile motor ignition test. This test was conducted to evaluate the effects of an accidental motor ignition while the projectile was in an unconfined area.

The projectile was placed, unrestrained and in a horizontal position, in a wooden trough 4 1/2 feet high. The igniter was initiated and the rocket motor ignited normally after the 23-second delay. The projectile launched itself downrange in a horizontal position with a slight nose-down angle, impacted flat at about 300 feet from ground zero, again at 690 feet, and again at 1,200 feet, at which time the nose of the projectile dug into the ground causing the projectile to tumble end-over-end for the remainder of the flight. It came to rest, with the motor still burning, at a point 2,620 feet from ground zero and 20 feet to the right of the flight path. Figure 18 shows the projectile at the final resting place.

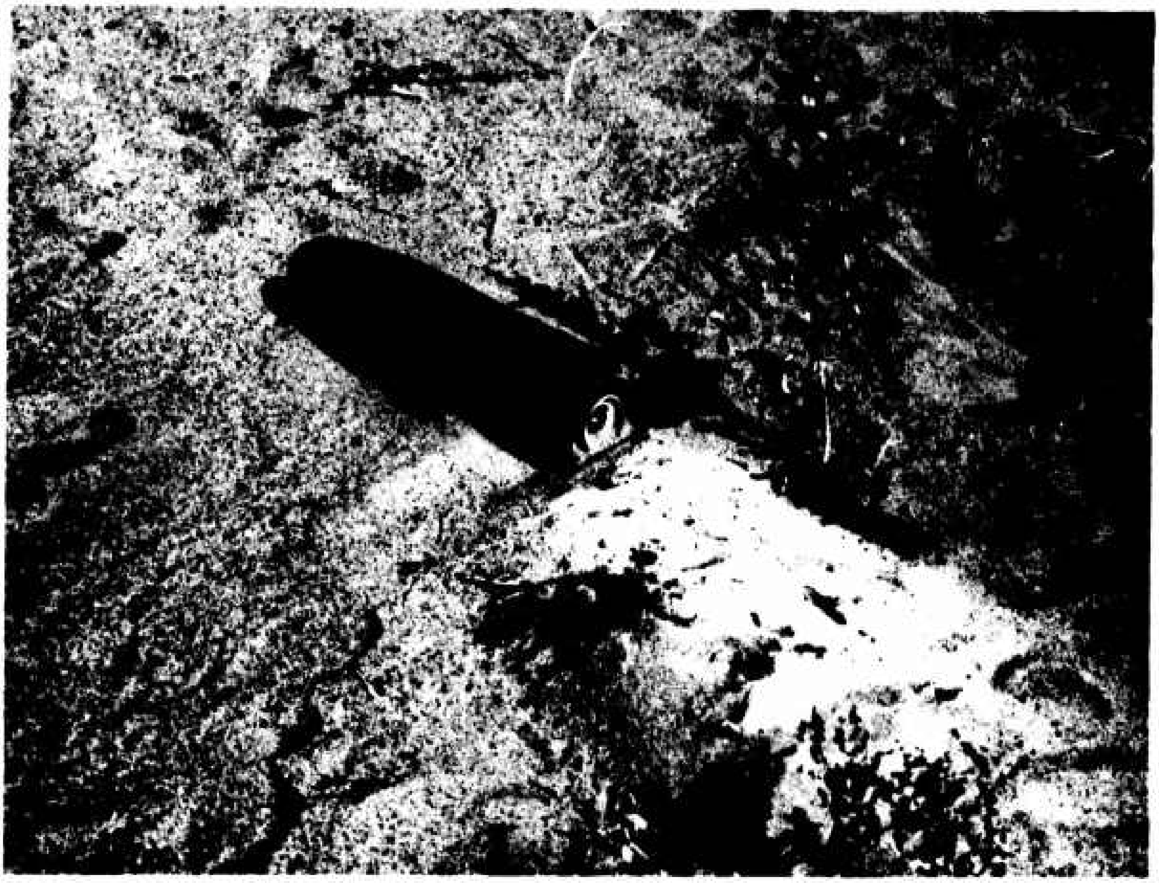

FIG. 18. Aft-End View of TM-9C After Unrestrained-Projectile Ignition Test. The motor burned for a short time after the projectile came to rest 2,620 feet from the launch point. The fuze remained in the safe condition.

The projectile body exhibited very little damage as a result of the test. There was a definite indication of the first impact on the ogive of the warhead and the graphite nozzle was missing. A sharp report was heard coincident with the first impact, indicating that at this point in the flight the motor overpressurized and expelled the nozzle. The fuze was shattered and carried away on the third impact. Fragments of the fuze were found scattered over this area. The fuze adapter and AD fuze were still in the nose of the projectile. The AD fuze arming mechanism was located and was found to be in the safe condition.

EXPOSURE TO GUN MUZZLE BLAST

Two projectiles were subjected to the blast of a 5"/38 gun to determine the blast effect on the RAP igniter and the Mk 357 Mod 0 CVT Fuze and Adapter Assembly. Both projectiles were inert, one fitted with an igniter and the other with a Mk 357 fuze. The projectiles were placed vertically, fuze and igniter up, 5 feet in front and 5 feet below the muzzle of a 5"/38 gun. A standard projectile was then fired through the gun with a standard service charge. Both test projectiles were knocked over; however, the igniter and fuze were unaffected by the blast.

GUN-FIRED WITH CLEARING CHARGE

A RAP was gun-fired with a standard clearing charge to evaluate RAP compatibility with standard Fleet gun-clearing practices. A clearing charge, which contains 9.0 pounds of propellant compared to 15.2 pounds for a standard service charge, is most often used to clear a barrel after a standard service charge misfires.

The RAP, an all-up round with a Mk 357 CVT Fuze and Adapter Assembly, was fired from a first-quarter-life barrel at a 45-degree quadrant elevation. The igniter and motor functioned satisfactorily, attaining a range of 19,278 yards. This indicated that safety practices were not compromised by using a clearing charge with RAP. However, the fact that a clearing charge could ignite a RAP was included in Fleet training doctrine and a recommendation made that appropriate caution be exercised in such a situation.

IGNITER DROP

Igniter drop tests were conducted to evaluate igniter safety characteristics when, if the projectile were accidentally dropped, the igniter struck a protrusion, such as a rivet head. The igniters were attached to a 57- or 60-pound slug and dropped, aft end down, onto a 3/4-inch-diameter steel stud with the end rounded to simulate a rivet head. Results for the test series are given in Table 3.

TABLE 3. Igniter Drop Test Summary.

Igniter configuration		Drop height, ft					
		1/2	1	1 1/2	2	2 1/2	3
Series I							
Mk 279 Mod 0	Fire		0	0	0	1	1
	No fire		1	1	1	0	0
Series II							
Mk 279 Mod 0 (with M-35 primer)	Fire	0	1	5	6		
	No fire	6	5	1	0		
Series III							
Mk 279 Mod 1	Fire				0		0
	No fire				6		6
Mk 279 Mod 1 (dropped on flat steel plate)	Fire						0
	No fire						6
Mk 279 Mod 1 (with No. 34 primer)	Fire			0	0	4	
	No fire			6	6	2	

The initial tests were with Mk 279 Mod 0 igniters. Five drops with a 57-pound slug produced similar damage to igniter housing and retainer, leaving a ball-shaped depression. A drop of more than 2 feet was required to fire the primer, indicating that igniter sensitivity was acceptable.

At this point in the program, all safety tests were complete and the 5"/38 RAP was released to the Fleet. However, flight tests indicated a need for greater igniter reliability (the igniter misfired in 16 of 514 projectiles). Accordingly, an igniter product improvement program was initiated that recommended the No. 34 primer be replaced by the more sensitive M-35 primer. Also, the housing and spring were modified to optimize spring action, thereby increasing reliability. A second series of drop tests, this time with a 60-pound slug, resulted in 100% actuation at drop heights of 2 feet, and one unit fired when dropped from 1 foot. However, the units passed 40-foot drop tests (three drops, no ignition) and also withstood 320°F for 4 hours with no autoignition. On one of the autoignition test units the temperature rose to 480°F, which melted the rocket motor plastic shipping cap, but did not initiate the primer or ignition charge. Upon examination of the units dropped on the steel stud, it was evident that the units fired when the stud forced the spring retainer into the spring, which then flexed and fired the primer. The retainer was redesigned to withstand the forces involved and the drop tests were rerun. This design was capable of withstanding a 3-foot drop without firing. Similar igniters, but with No. 34 primers, were tested for comparison. These units could withstand only a 2-foot drop without firing. Six units with M-35 primers were also dropped from 3 feet onto

a flat steel plate; none fired. The igniter with the M-35 primer and modified retainer and housing was designated the Mk 279 Mod 1. Three of these units were loaded into RAP with inert motors and warheads and subjected to a 40-foot drop test (horizontal, base down, nose down); no igniter actuation was incurred. Subsequently, the three 40-foot drops were repeated with live motors and inert warheads; no igniter actuation occurred and all three projectiles were safe-to-handle for disposal.

CONCLUSIONS

Based on the results of the safety test program, it was concluded that RAP can be handled, stowed, and fired as safely as in-service 5-inch projectiles loaded with Composition A-3. The presence of a solid-propellant rocket motor and percussion-actuated igniter did not present an unusual safety hazard. Conclusions in each of the areas of investigation were as follows:

1. Environmental sequence - All RAP were safe-to-handle for disposal by qualified personnel after sequential treatment of temperature/humidity, transportation vibration, and 40-foot drop.

2. Slow cookoff - All reactions occurred within the boundries established by WR-50.

3. Fast cookoff - It could not be determined whether the warheads passed or failed the WR-50 requirements because of the lack of valid interface temperature data. However, the minimum measured time to a reaction of the explosive was judged a reasonable safety factor.

4. Bullet impact - Although RAP did not meet passing criterion established by WR-50, RAP did not appear to be any more hazardous than in-service projectiles.

5. Adjacent detonation and propagation - RAP did not appear to possess any characteristics other than those that would normally be expected.

6. Rocket motor blast - Rocket motor blast on an adjacent projectile reasulted only in motor ignition when placed base-to-base. No violent reaction characteristics are assosciated with rocket motor blast.

7. Unrestrained ignition - The only hazard is that of an unrestrained projectile; the fuze does not arm.

8. Gun muzzle blast - RAP does not react when exposed to gun muzzle blast.

9. Clearing-charge firing - RAP can be cleared from the gun using standard clearing practices without compromising safety practices.

10. Igniter drop - The Mk 279 Mod 1 igniter is sufficiently insensitive that it will withstand an accidental drop of at least 3 feet, even when a 3/4-inch-diameter protrusion strikes the igniter on center.

A final area of safety, that of identification, presents no hazard to those handling or firing RAP, but could be hazardous to those in the field. In view of the similarity in appearance between conventional and RAP projectiles and the dissimilarity of impact points, positive and correct identification by handling crews becomes a major safety factor. For example, a gun crew could be under the impression it is firing RAP over the heads of our assault force, when it is actually firing standard projectiles into the midst of the force it is supporting. Therefore, extreme caution must be used in firing operations.

Appendix

5"/38 AND 5"/54 IN-SERVICE PROJECTILE BULLET IMPACT TEST

This appendix was extracted from "Reg. 4533-59-69, 5"/38 and 5"/54 In-Service Projectile Bullet Impact Test", which was issued by the Test Management and Product Evaluation Branch (Code 4533), Naval Weapons Center (NWC), China Lake, California.

INTRODUCTION

Four Mk 41 Mod 0 FCL/VT 5"/54 and four Mk 49 Mod 1 FCL/VT 5"/38 projectiles were subjected to a 20 mm bullet impact test in accordance with the specifications set forth in Naval Weapons Requirements WR-50 during the period of 27 September 1968 to 30 September 1968. The eight projectiles were standard 5-inch "in-service" projectiles loaded with Compositions A-3 explosive. The Mk 41 projectiles were configured with Mk 73 Mod 4 self-destructing (SD) variable time fuzes (VTF). The Mk 49 projectiles were configured with Mk 71 Mod 8 SD VTF.

The testing was conducted to compare the effects of a 20 mm round impacting the standard projectiles at a nominal service velocity of 2,700 $\pm$100 feet per second with tests previously conducted with the 5"/38 and 5"/54 Rocket Assisted Projectiles (RAP) as the test specimens. The criteria for passing this test is that no violent reactions such as a detonation or deflagration shall occur when the projectile is impacted by a 20 mm M95 nonincendiary armor piercing (AP) round.

TEST RESULTS

The following is a summary of observations made at the time of impact of the 20 mm round and during the subsequent inspection of the test site.

Mk 49 Mod 1 5"/38 Projectiles

PROJECTILE NO. 1

1. Smoke cloud and audible report at impact.

2. Projectile base still intact, 5 feet to the rear of stand.

3. Projectile fragments were scattered over an area of 55 yards radius from ground zero (Fig. 19).

4. No explosive fragments found within the 55-yard radial area.

PROJECTILE NO. 2

1. Smoke cloud and audible report at impact.

2. Projectile base and rotating band still intact at ground zero.

3. Explosive fragments found over an area 10 feet in diameter (Fig. 20).

4. Projectile fragments recovered in an area of 118 yards radius (Fig. 20).

5. Fuze, still fairly intact, found 90 yards from ground zero.

PROJECTILE NO. 3

1. No smoke or audible report at impact.

2. Penetration of outer case upon entry but did not exit.

3. Aft side of case split approximately 4 inches (Fig. 21).

4. Visible evidence of slight burning both at the point of entry and 4-inch split.

PROJECTILE NO. 4

1. No smoke or audible report at impact.

2. Complete penetration, splitting aft side of case (Fig. 22).

3. No evidence of burning.

4. Minute fragments of explosive at ground zero.

<u>Mk 41 Mod 0 5"/54 Projectiles</u>

PROJECTILE NO. 5

1. Smoke cloud and audible report at impact.

2. Projectile base with rotating band intact, 4 feet to rear of support stand.

3. Large explosive fragments recovered within radius of 48 yards from ground zero (Fig. 23).

4. Large projectile case fragments and explosive fragments found 140 yards from ground zero (Fig. 23).

5. Fuze, still fairly intact, found 63 yards from ground zero.

PROJECTILE NO. 6

1. Smoke cloud and audible report at impact.

2. Projectile base found intact, 6 feet to rear of support stand.

3. Large explosive fragments found at ground zero.

4. Large segment of rotating band found 8 feet from ground zero.

5. Projectile case fragments and explosive fragments found within a radius of 75 yards of ground zero (Fig. 24).

6. Fuze found partially intact, 84 yards from ground zero.

PROJECTILE NO. 7

1. Smoke cloud and audible report at impact.

2. Projectile base intact, with the rotating band in place, found 10 feet from ground zero.

3. Large fragments of explosive found at ground zero (Fig. 25).

4. Projectile case fragments and small fragments of explosive were found within 52-yard radius of ground zero (Fig. 25).

5. Fuze, still intact, found 60 yards from ground zero.

PROJECTILE NO. 8

1. Smoke cloud and audible report at impact.

2. Projectile base found 10 feet to rear of support stand and intact.

3. Large quantities of explosive found in the area of ground zero (Fig. 26).

4. Fragments of projectile case and explosive found within a 145-yard radius of ground zero (Fig. 26).

5. Fuze, with forward section missing, found 82 yards from ground zero.

CONCLUSIONS

Examination of the photographs of the recovered fragments, contained in this report, by personnel of the NWC Warhead Analysis Branch (Code 4561) led to the following conclusions:

1. 5"/38 projectile No. 1 suffered a low-order detonation.
2. 5"/38 projectile No. 2 suffered a deflagration.
3. 5"/38 projectiles No. 3 and 4 neither deflagrated nor detonated.
4. 5"/54 projectiles No. 5 through 8 suffered deflagrations.

FIG. 19. Recovered Fragments of Mk 49 Mod 1 5"/38 Projectile No. 1 (LHL 136354).

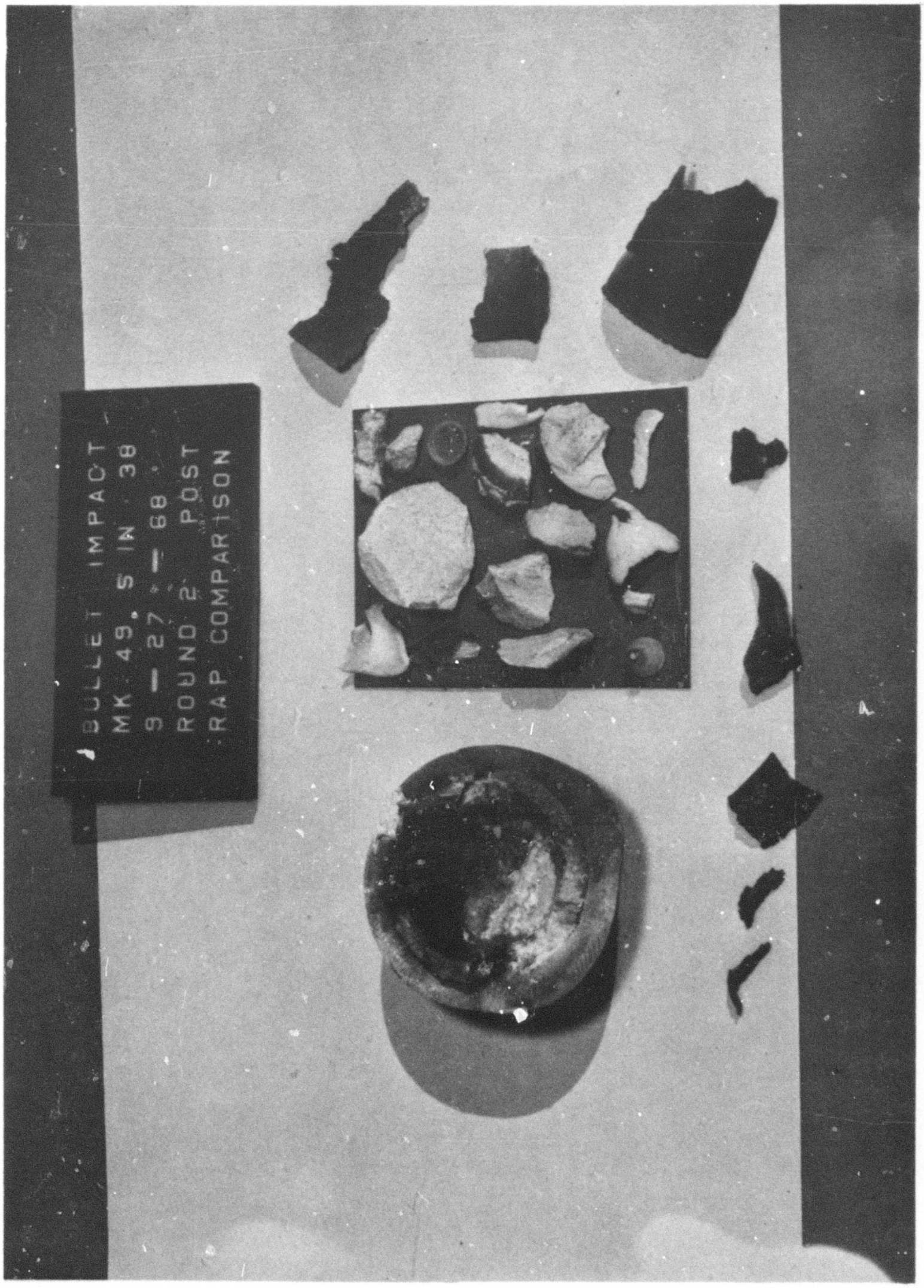

FIG. 20. Recovered Fragments of Mk 49 Mod 1
5"/38 Projectile No. 2 (LHL 136345).

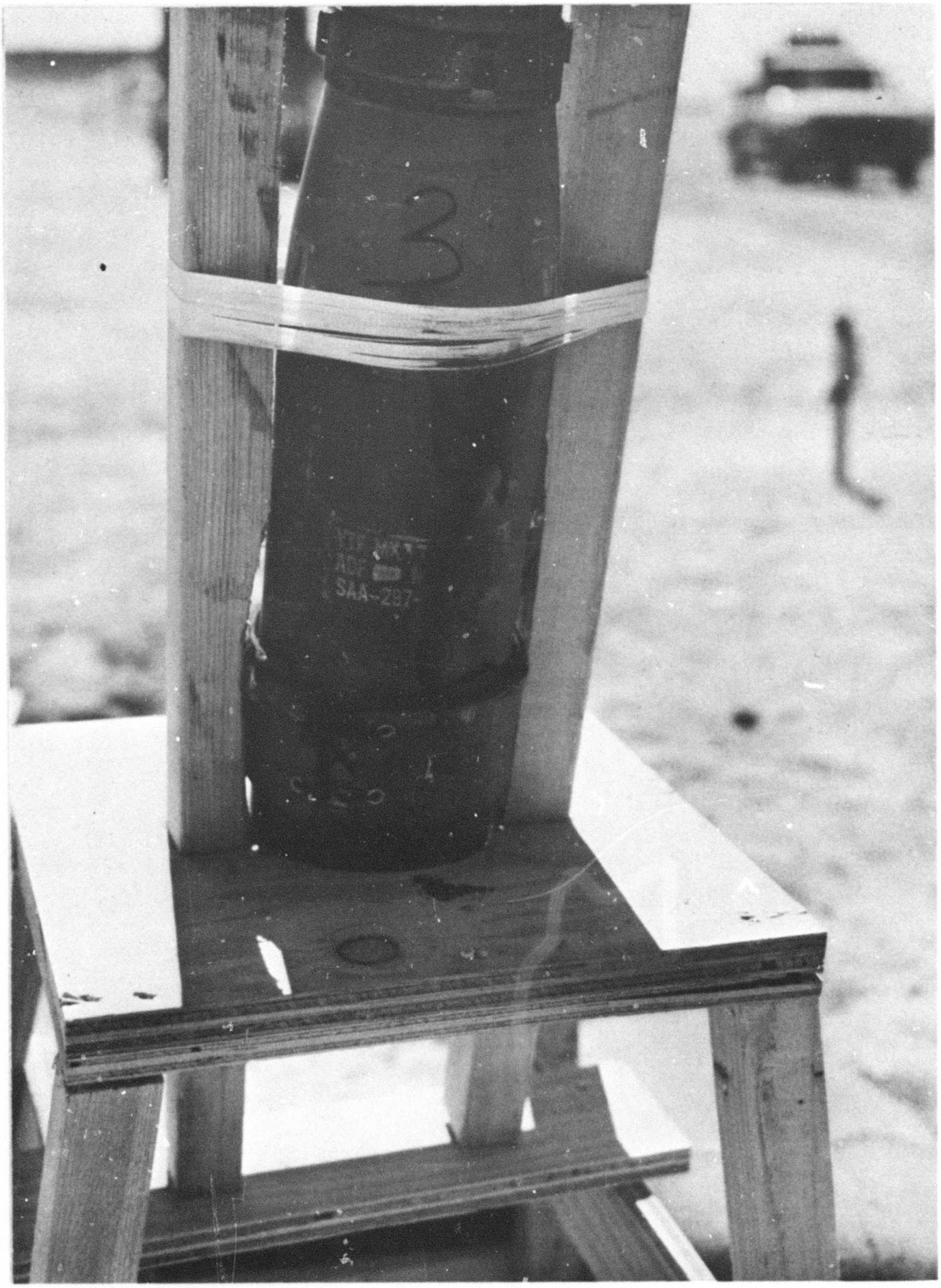

FIG. 21. Post-Test View of Aft Side of Case,
Mk 49 Mod 1 5"/38 Projectile No. 3 (LHL 136356).

FIG. 22. View of Exit Side of Mk 49 Mod 1
5"/38 Projectile No. 4 (LHL 136348).

FIG. 23. Recovered Fragments of Mk 41 Mod 0 5"/54 Projectile No. 5 (LHL 136349).

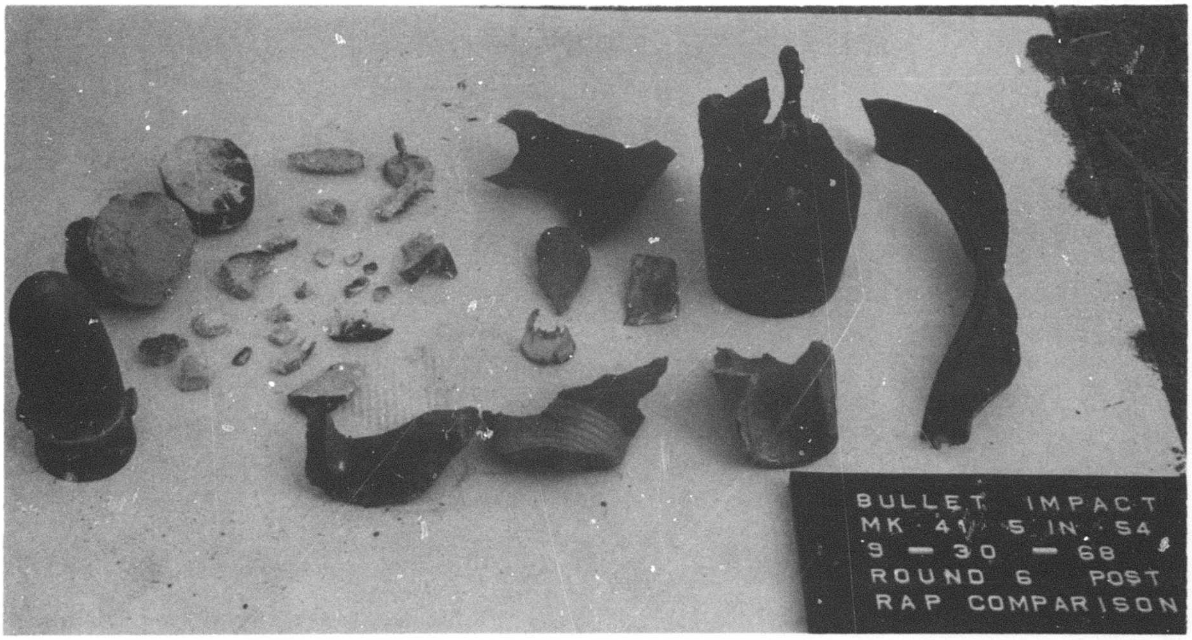

FIG. 24. Recovered Fragments of Mk 41 Mod 0
5"/54 Projectile No. 6 (LHL 136368).

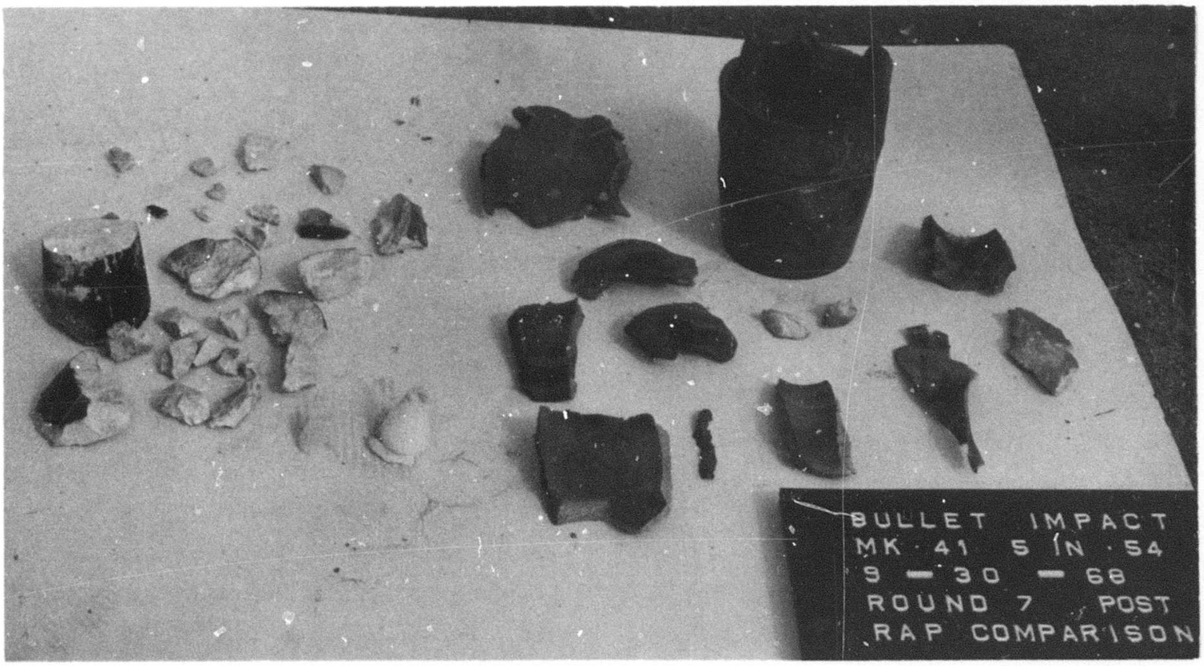

FIG. 25. Recovered Fragments of Mk 41 Mod 0
5"/54 Projectile No. 7 (LHL 136366).

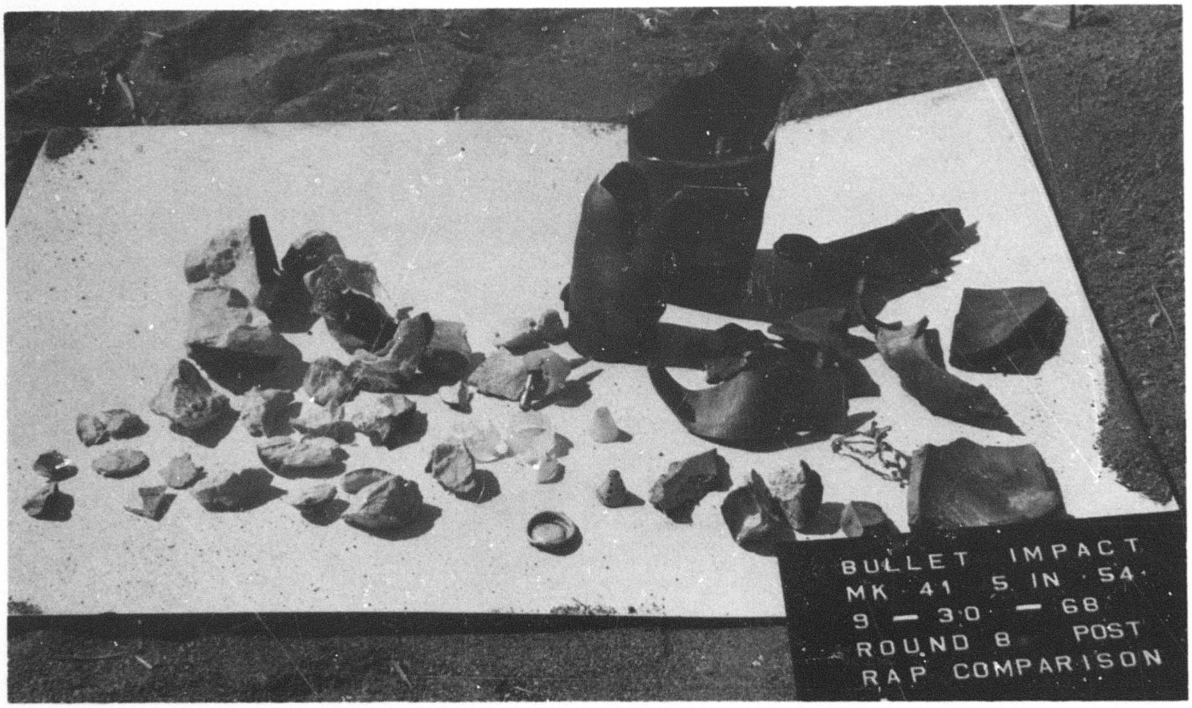

FIG. 26. Recovered Fragments of Mk 41 Mod 0 5"/54 Projectile No. 8 (LHL 136365).

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Summary

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13. ABSTRACT

The Safety Test Program for the 5-inch 38 caliber Rocket Assisted Projectile (5"/38 RAP) verified that RAP can be handled, stowed, and fired as safely as existing in-service projectiles loaded with Composition A-3 explosive. The presence of a solid-propellant rocket motor and percussion-actuated igniter did not present any unusual safety hazard. Sequential environmental, bullet impact, and slow and fast cookoff tests were conducted as required. ~~by WR-50 and MIL-R-23139.~~ Optional and additional evaluations included rocket motor blast, adjacent detonation, propagation, ignition and unrestrained projectile, exposure to gun muzzle blast, gun-fired with clearing charge, and special igniter drop tests.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Cookoff test Bullet impact Propagation Rocket Assisted Projectile Environmental Percussion-actuated igniter Drop test						

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